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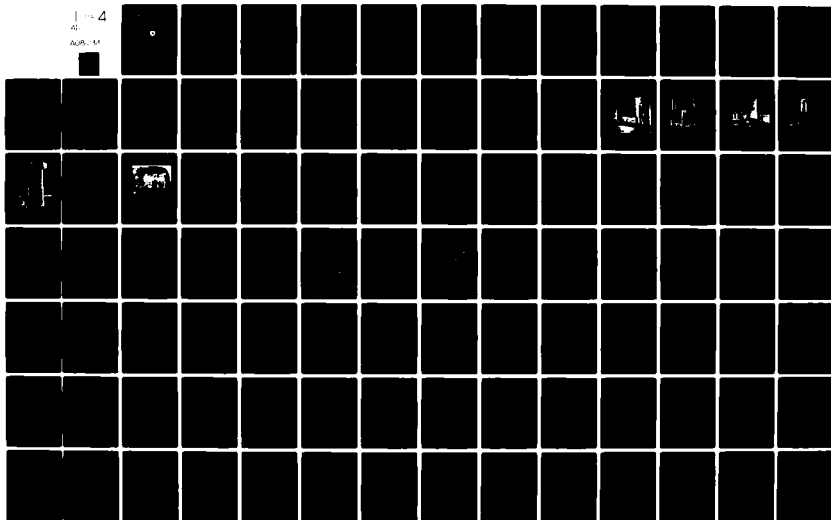
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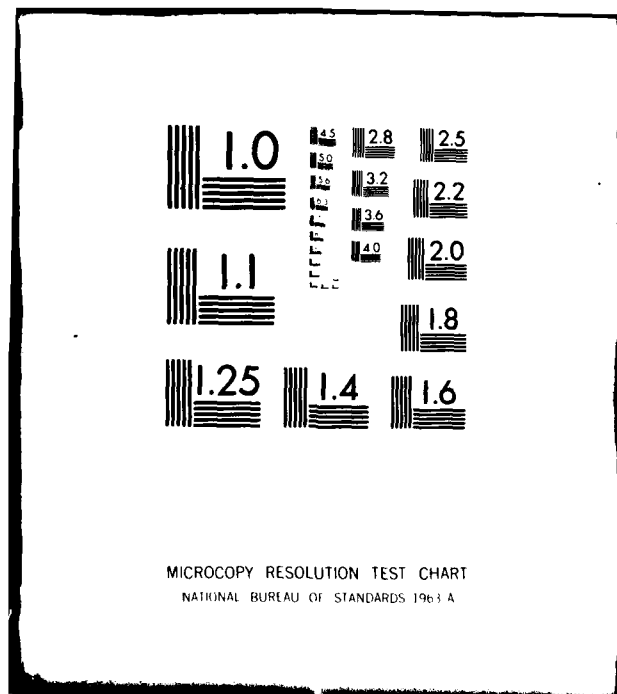
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MICROWAVE LANDING SYSTEM PHASE III

(Basic Narrow and Small Community Configurations)



JUNE 1978

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Volume I

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13. Abstract This report describes the design, fabrication, and testing of a Basic (Narrow) and a Small Community configuration for the Microwave Landing System (MLS). A detailed description of the ground and airborne subsystems and equipments, and a summary of flight test data taken at the National Aviation Facilities Experimental Center (NAFEC) are presented. The sitings of the two configurations at NAFEC are described. A summary of the reliability and maintainability analysis is given; the detailed R&M analysis is presented in Vol. II, Appendices B thru E.		14. Type of Report and Period Covered (9) Final Report, Vol. I
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SUMMARY

The Bendix Communications Division of The Bendix Corporation was tasked, as prime contractor under DOT/FAA Contract DOT-FA72WA-2801, to design and fabricate two prototype Microwave Landing System configurations and to install them at the National Aviation Facilities Experimental Center (NAFEC) at Atlantic City, New Jersey.

The Basic Narrow configuration included ground azimuth, ground elevation, and DME subsystems and four airborne receivers. The Small Community configuration included ground azimuth and elevation elements and four airborne receivers.

The task has been successfully completed with the Basic Narrow and Small Community Ground Subsystems delivered to NAFEC in May 1976 and July 1976, respectively. The airborne subsystems have been installed and evaluated in numerous test aircraft. Independent field and flight testing by FAA (NAFEC) and Bendix personnel have proven that both systems meet or exceed the specified performance requirements.

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SECTION 1.

INTRODUCTION

1.1 GENERAL

This final report is submitted in compliance with paragraph 10.2 of the Statement of Work under Department of Transportation Contract DOT-FA72WA-2801, as amended. This contract called for the development and testing of a Basic Narrow (BN) configuration and a Small Community (SC) configuration for the Microwave Landing System (Phase III). This report includes complete descriptions of the Basic Narrow and Small Community configurations and the airborne receivers, a description of all tests performed and typical results, a summary of the reliability and maintainability analyses, detailed siting criteria, and recommendations for design improvements.

1.2 PROGRAM OBJECTIVES

Under the Five-Year Microwave Landing System (MLS) Development Program Plan, three major phases are identified. The purposes of Phases I and II were to develop hardware and techniques that would satisfy the MLS requirements and to demonstrate the feasibility of the developed system. The current program, Phase III of the Development Program Plan, is a logical continuation of Phases I and II.

The primary purpose of Phase III is to develop and test a prototype MLS system. The end product of this phase will be a family of production specifications for various ground and airborne MLS configurations. In order to properly accomplish these goals, Phase III included comprehensive systems analyses and extensive laboratory, field, and flight test evaluations. The depth of the analyses and tests was to be sufficient to facilitate later development of end item design requirement specifications, schedules, and cost data.

As such, the Phase III effort had to demonstrate the capability of the developed systems to (1) satisfy the specified functional and operational requirements; (2) meet the technical design requirements and assure that the designs are technically sound, reliable, and safe to use; and (3) comply with reliability and maintainability requirements.

1.3 SUMMARY OF TASK

To accomplish the objectives of Phase III, the Bendix Communications Division was contracted to develop and deliver

two MLS system configurations - a Basic Narrow and a Small Community. The Bendix/Bell MLS team was maintained during Phase III. The Bendix Communications Division had the prime responsibility for the ground subsystem and overall system integration. The expertise of the Bendix Avionics Division was called upon for the airborne receiver design, while Bell Aerospace Textron had responsibility for assisting in development of the monitoring system and contributing to systems analysis.

The successful accomplishment of the Phase III objectives involved four fields of effort - the design and assembly of the system components, complete and thorough testing of the system and its major subsystems, an extensive analytical evaluation, including in-depth computer simulation, and generation of a descriptive data package. The design, assembly, and installation of the equipments at NAFEC were accomplished on schedule within the relatively short time span of twelve months. After installation, field support was provided to FAA personnel at NAFEC during the field test phase. Concurrent with this, generation of test program specifications, instruction and technical manuals, production specifications, and this final report were accomplished.

The design phase of the task involved both the design of new equipments which advanced the state-of-the-art and the redesign of equipment developed during Phases I and II to improve performance, reduce costs, and increase commonality. During Bendix' participation in Phases I and II, phased arrays had been used exclusively for the scanning beam antennas. For Phase III, at the Government's request, beam port antennas were proposed. Since these antennas are significantly different than phased array antennas, a concerted analysis was performed to select the optimum beam port antenna type. After a thorough engineering evaluation of several candidates, a Rotman lens was chosen as most applicable to the MLS. Since a Rotman lens is scanned by sequentially exciting the lens inputs, this selection necessitated the procurement of microwave switches. Concurrent with the development of the switch specifications, a means of stepping the beam in finer increments than that afforded by exciting adjacent lens inputs was devised. This required the development of another microwave device, the fine-scan modulator.

The selection of the Rotman lens also affected the beam steering electronics to a significant degree and required a major redesign of this equipment.

The monitoring system also had to be modified to include the new array components and the redesigned beam steering system. Although redesign of the other major equipments was not necessary.

to obtain a working system, a considerable effort was expended in upgrading the performance of circuits, increasing the commonality, and improving reliability and maintainability.

Several computer simulations were developed and implemented on the GA 18/30 at Bendix. These simulation programs included

- interactive design of Rotman lens
- effects of multipath
- scanning beam accuracy, using a model of the airborne receiver.

Part of the Phase III effort included the development of a data package which includes this final report, an as-built drawing package, and operation and maintenance manuals for both SC and BN systems. In addition, the customer was kept abreast of progress through Bendix participation in Design Review Board meetings which were held on an average of every two months during the design phase of the program. These meetings were of mutual advantage; they enabled the FAA to keep informed of the Bendix design philosophy and permitted Bendix, within the scope of the contract, to incorporate features into the design that were consonant with the latest MLS requirements and specification changes.

In summary, the major accomplishments during the Phase III contract were:

- (a) design of Basic Narrow and Small Community Systems, including airborne equipment
- (b) fabrication, integration, and field testing of these systems
- (c) comprehensive analysis and simulation that enabled accurate prediction of system performance and integrity
- (d) generation of a data package that included O&M manuals and a complete drawing package.

Figures 1-1 through 1-5 are photographs of the Basic Narrow and Small Community equipments installed at NAFEC. Figure 1-1 shows the BN AZ antenna enclosure which contains the scanning beam array. Figure 1-2 shows the BN AZ electronics shelter. The two antennas in the foreground are the forward ident (shown on the left) and the DME. Also visible is one of the two sidelobe suppression (SLS) antennas. Figure 1-3 shows

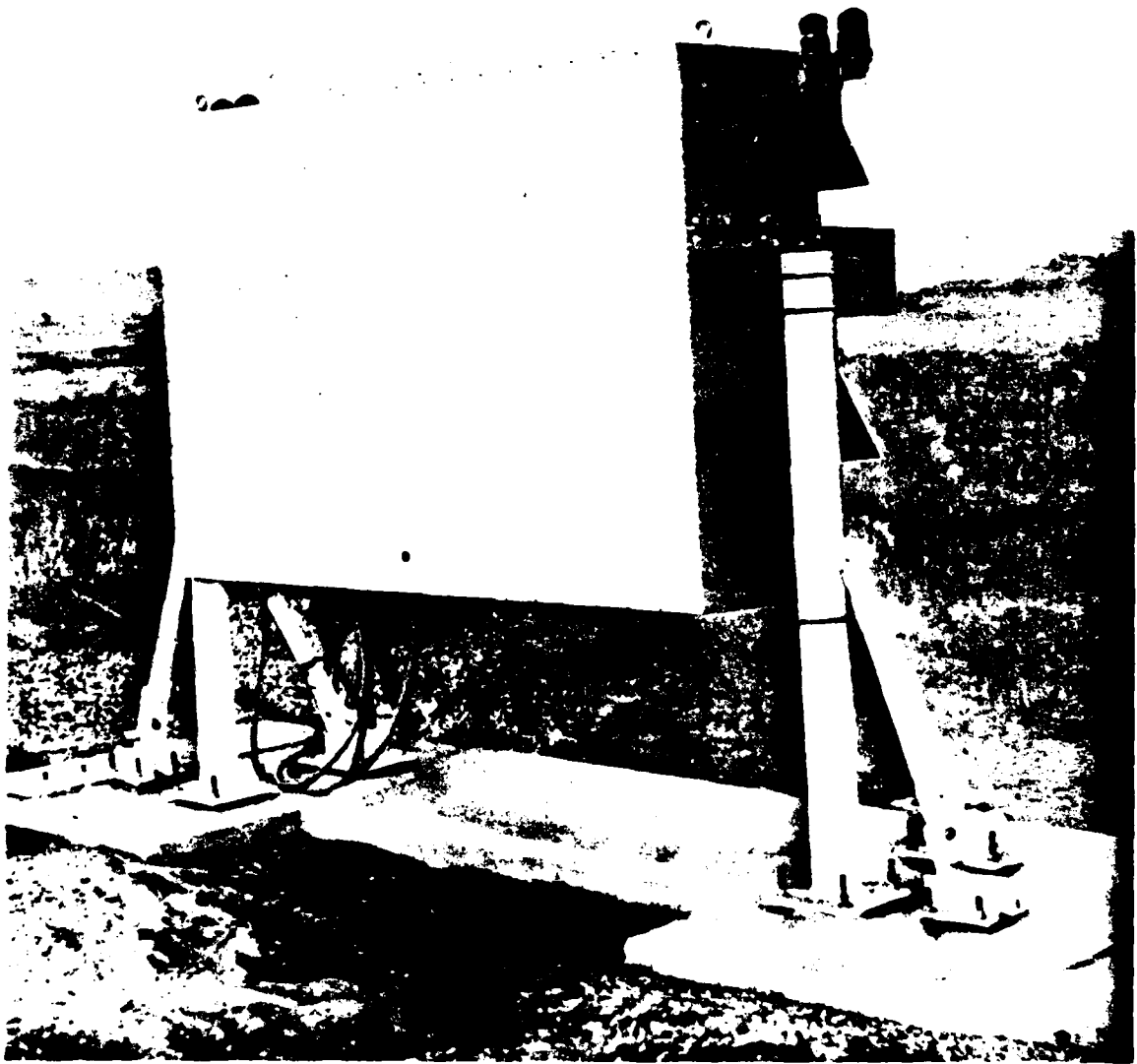


FIGURE 1-1. BASIC NARROW AZ
ANTENNA ENCLOSURE



FIGURE 1-2. BASIC NARROW AZ
ELECTRONIC SHELTER

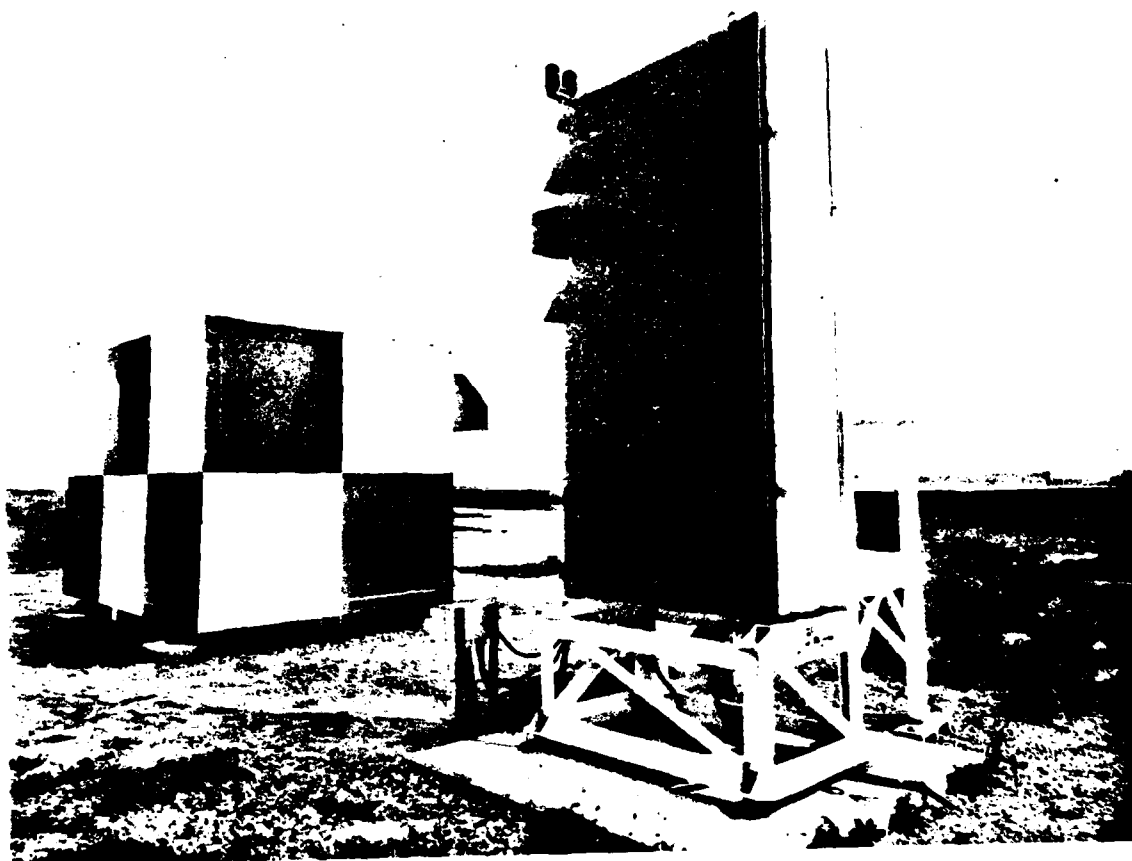


FIGURE 1-3. BASIC NARROW EL ENCLOSURE
AND ELECTRONICS SHELTER

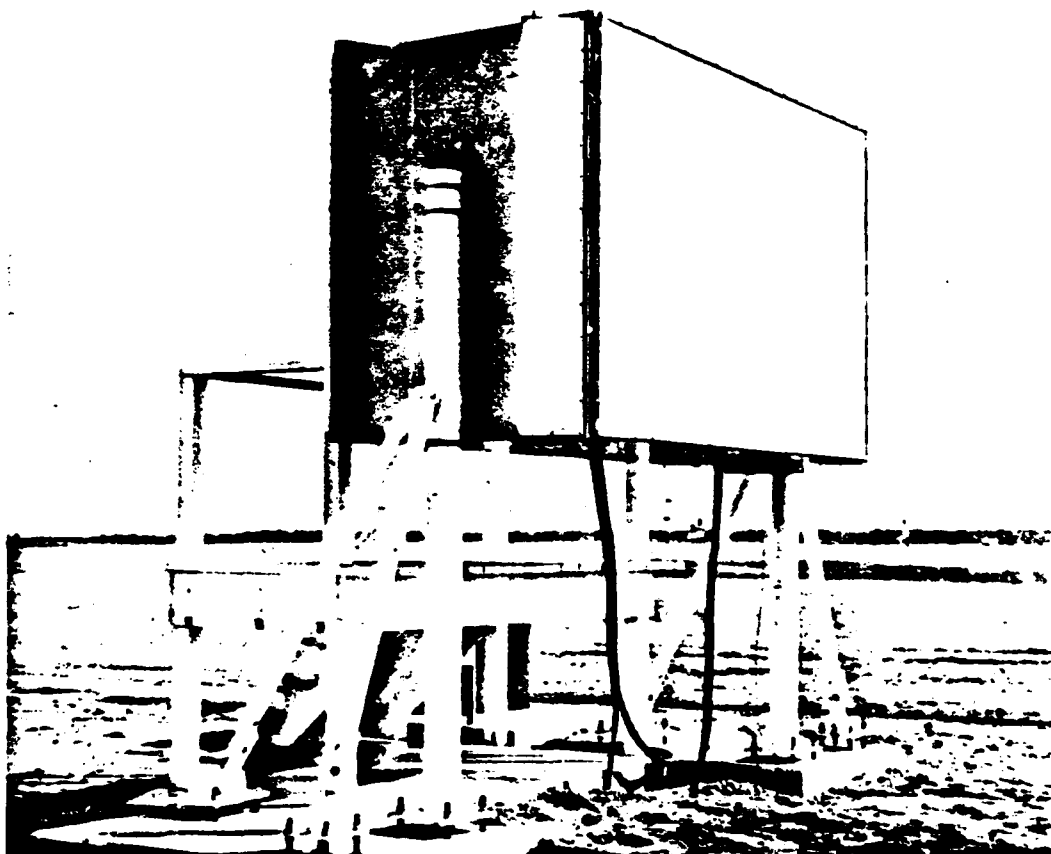


FIGURE 1-4. SMALL COMMUNITY AZ SUBSYSTEM

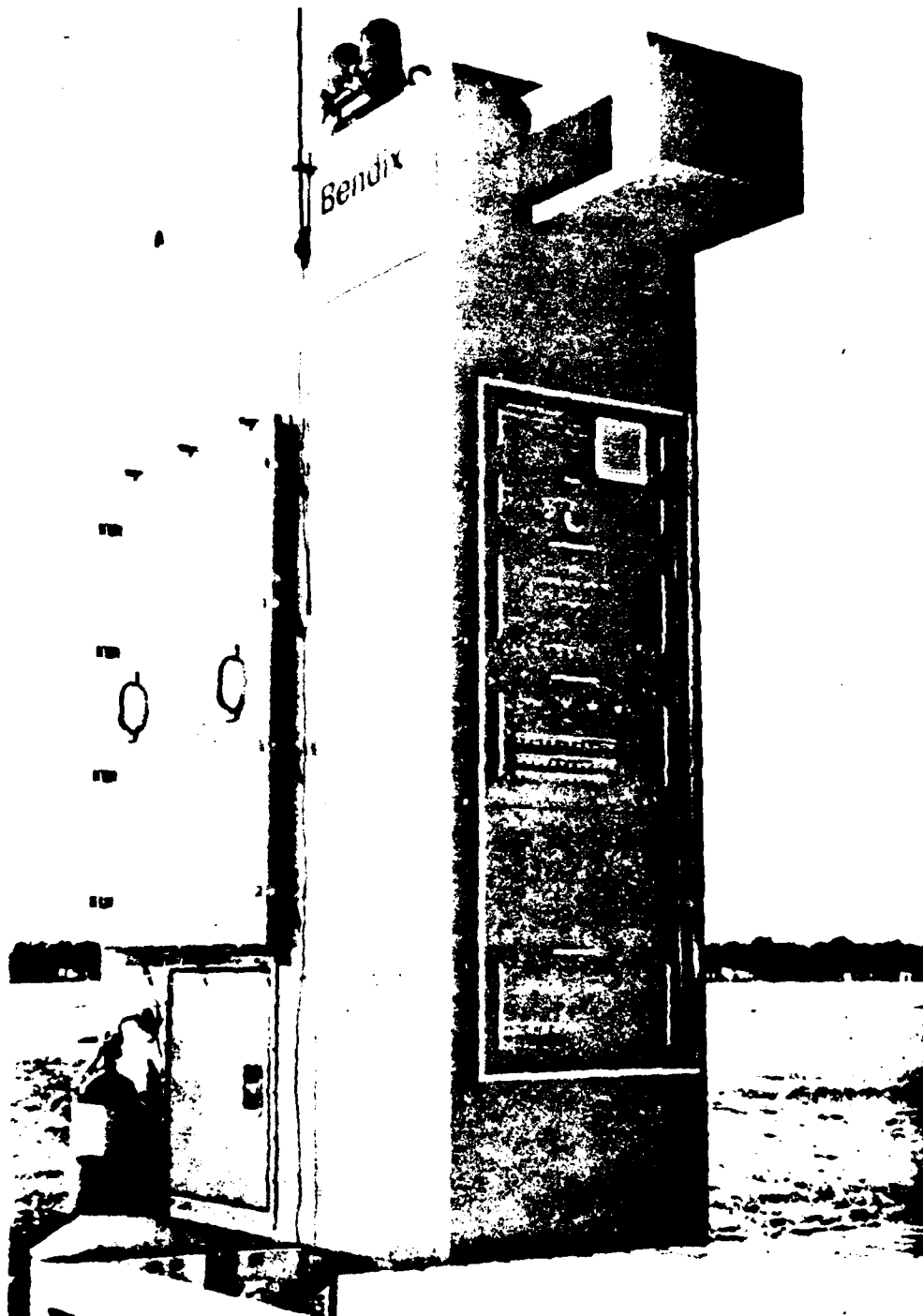


FIGURE 1-5. SMALL COMMUNITY EL SUBSYSTEM

the BN EL antenna enclosure and electronics shelter. All antennas are located in the antenna enclosure. The left radome contains the forward ident and upper SLS antennas; the right radome contains the scanning beam array.

Figure 1-4 shows the SC AZ subsystem. The two antennas on the forward corners are SLS antennas. A third SLS antenna is located on the rear of the enclosure. The large radome contains the scanning beam array and the left and right sector guidance and forward ident antennas.

Figure 1-5 is a rear view of the SC EL subsystem with an enclosure cover removed to show the controls and monitor equipments.

Figure 1-6 shows the BN airborne equipments. The equipments from left to right are the DME interrogator, the angle receiver, and, from top to bottom, the DME indicator, the control panel, and the auxiliary data panel. The SC airborne equipments, not shown, include the control panel and a smaller version (approximately one-half the height) of the angle receiver.

1.4 CONTENTS OF REPORT

The remainder of this report is divided into eight major sections, plus an addendum containing appendices. In Section 2, an overview of the four major subsystems (BN and SC ground subsystems and the related airborne subsystems) is presented. First, the system specifications are discussed and the more pertinent system requirements are defined. Next, the BN and SC Ground Systems are described in sufficient detail to permit system features and performance to be defined. Included in this description are the physical configuration, system block diagrams, signal formats, power budgets, system interfaces, and system accuracies and performance. In this section, the airborne equipments are also described to the same level.

In Section 3, a detailed description of the BN and SC Ground Systems is presented. For each system, the performance and features of the major subsystems are listed, the physical parameters are defined, and all applicable drawings, schematics, and specifications are referenced.

A similar detailed discussion of the airborne equipment is given in Section 4.

Section 5 discusses all system and subsystem testing. This includes tests made at the Bendix plants, static and flight tests made at NAFEC, and an evaluation of the test results.

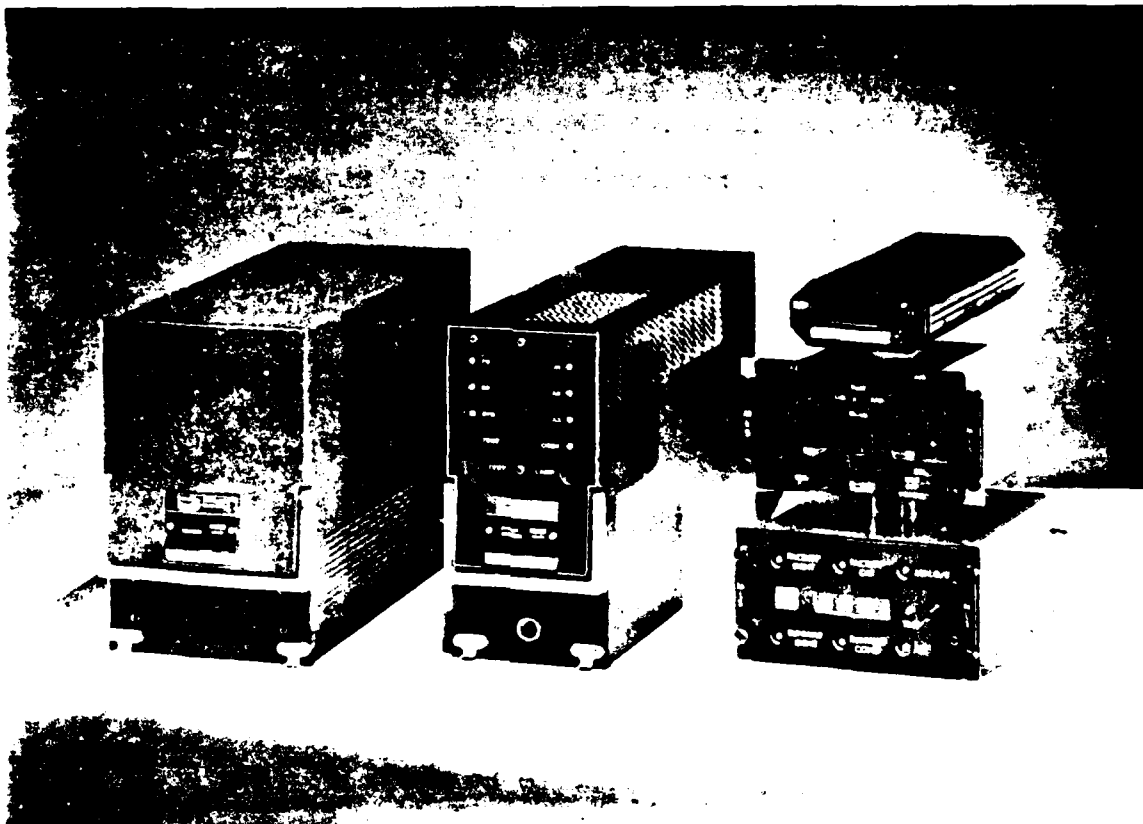


FIGURE 1-6. MLS AVIONICS - AIRLINE
CONFIGURATION AVIONICS COMPLEMENT.
FROM THE LEFT - PRECISON DME; THE
ANGLE GUIDANCE RECEIVER/PROCESSOR;
AND FROM THE TOP - THE DME DISPLAY;
THE CONTROL PANEL AND AUXILIARY
DATA DISPLAY.

Siting requirements are discussed in Section 6. Included in this discussion are the results of the collocation tests made at NAFEC with the Instrument Landing System (ILS) and Approach Light System (ALS).

A summary of the reliability and maintainability report is contained in Section 7. Enough detail is presented to confirm compliance with MLS requirements.

Section 8 presents the conclusions that were reached after an overall evaluation of the Phase III design and test efforts.

Lastly, in Section 9, recommendations for improving system design and performance are given. Both the ground and airborne systems are included.

There are six appendices included in the addendum to this report. Their contents are not required for a description of the MLS configurations, but they do provide additional information and back-up material. Appendix A describes some of the design considerations that had to be imposed in specifying parameters for the Rotman lenses. Appendices B, C, D, and E contain material on the reliability and maintainability analysis. Appendix F discusses the effects of rain on the MLS Phase III radomes.

SECTION 2.

GENERAL SYSTEM DESCRIPTION

2.1 INTRODUCTION

This section is devoted to presenting a detailed overview of the Basic Narrow (BN) and Small Community (SC) Ground Subsystems and the Airborne (A/B) equipments. Attention is concentrated on system features and performance. For the BN and SC descriptions, the elements of each system are defined, a system block diagram is presented, and the equipment deployment at NAFEC is described. Then a synopsis of the system performance is given, including such parameters as scan angles, antenna characteristics, accuracies, and error budgets. This is followed by descriptive sections on the power budget, the signal formats, interfaces, and monitoring.

For the airborne equipments, the system elements are defined and high level system block diagrams are presented. Then, functional descriptions of the equipments are given. The installations in the NAFEC test aircraft are also described.

Paragraph 2.2, immediately following, is a resume of the system requirements for the BN, SC, and A/B equipments. The BN ground subsystem consists of three functional elements: the approach azimuth (AZ), the approach elevation (EL), and distance measuring (DME). The SC subsystem is similarly configured except there is no DME element.

2.2 SUMMARY OF SYSTEM REQUIREMENTS

The requirements for the Basic Narrow and Small Community Ground Subsystems and the Airborne Equipment are summarized below. These requirements were obtained from:

FAA-ER-700-01	Basic Engineering Requirement, and Amendment 2, Changes 1-6
FAA-ER-700-04	Small Community Engineering Requirement, and Amendment 1, Changes 1-2
FAA-ER-700-07	Functional Requirements, and Amendment 2, Changes 1-2

These are as modified by the S.O.W., and are summarized here for ease of reference.

Common to both the Basic Narrow and Small Community systems are the following environmental specifications:

Altitude	0 to 45,900 Ft. Non-operational 0 to 13,000 Ft. Operational
Temperature	+10C to +50C attended facility -10C to +50C in sheltered area -50C to +70C outside
Relative Humidity	10% to 80% attended facility 5% to 90% in sheltered area 5% to 100% outside

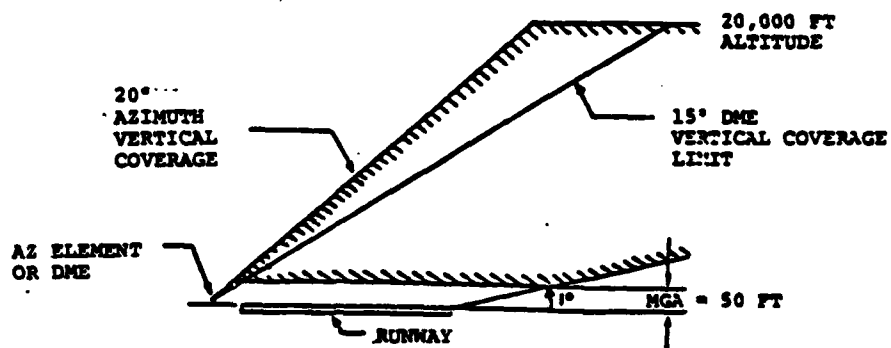
2.2.1 Basic Narrow Ground Subsystem Requirements

The Basic Narrow Ground Subsystem must provide approach guidance signals to aircraft within the volume defined by Table 2-1 and shown in Figures 2-1 and 2-2.

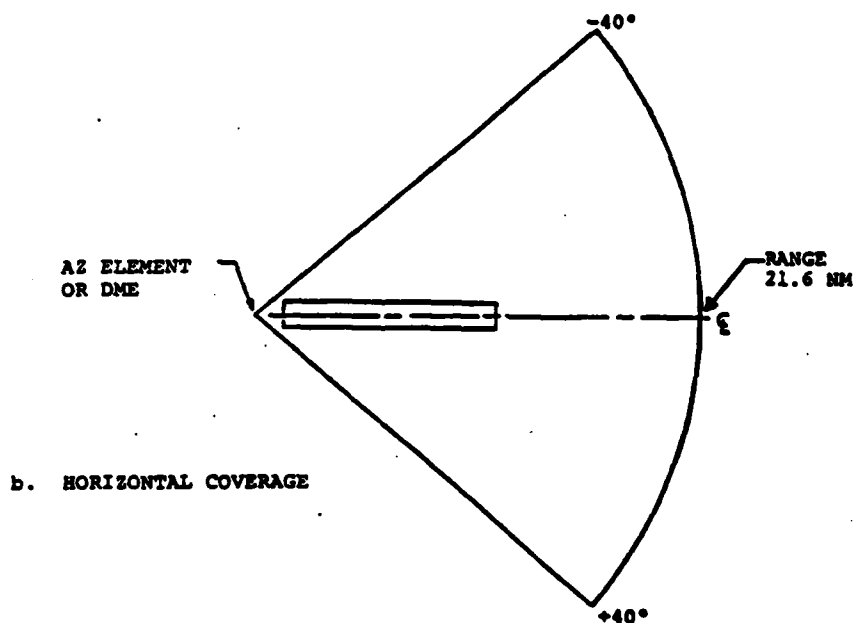
TABLE 2-1. BASIC NARROW GROUND SUBSYSTEM
COVERAGE REQUIREMENTS

FUNCTIONAL ELEMENT	MAX. ALTITUDE AGL (FT)	MAX. RANGE FROM EL (NM)	HORIZONTAL COVERAGE (DEG)		VERTICAL COVERAGE (DEG)	
			SYSTEM	PROPORTIONAL GUIDANCE	SYSTEM	PROPORTIONAL GUIDANCE
AZIMUTH (AZ)	20,000	20	±40	±40	1 - 20	1 - 20
ELEVATION (EL)				±40	1 - 15	1.9 - 10.67
DISTANCE (DME)				±40*	1 - 15	-

*Omni directional and forward sector (±40°) antennas provided.



a. VERTICAL COVERAGE



b. HORIZONTAL COVERAGE

FIGURE 2-1. BASIC NARROW AZ AND DME SUBSYSTEM COVERAGE REQUIREMENTS

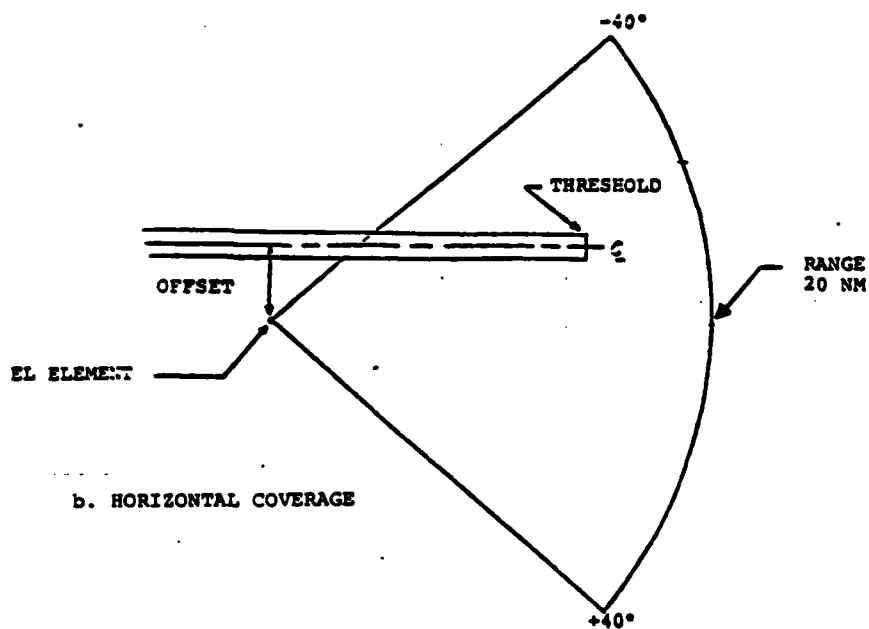
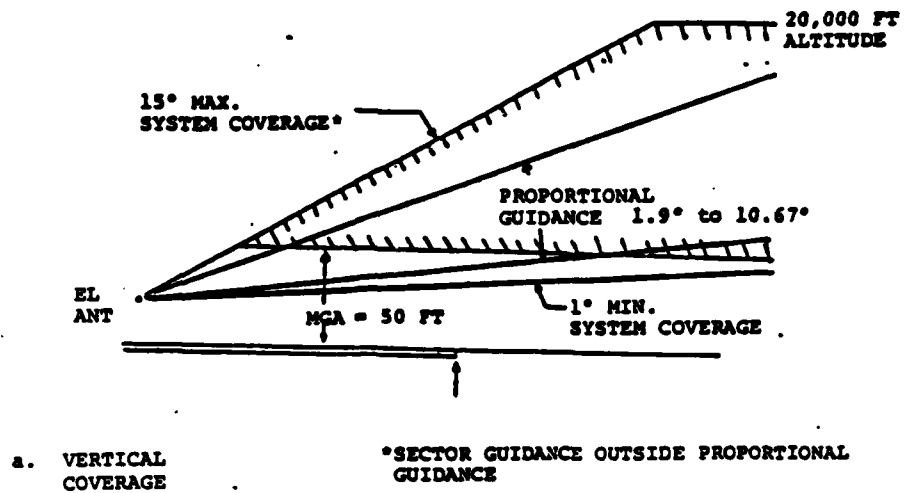


FIGURE 2-2. BASIC NARROW EL SUBSYSTEM COVERAGE REQUIREMENTS

The Basic Narrow 2σ system error window accuracies (ground, airborne, and propagation) are shown in Table 2-2. The error window for the AZ element is defined as being 8000 feet from the AZ antenna phase center measured along runway centerline. The DME element error window is 15,000 feet from the AZ antenna phase center. The EL element error window occurs at the intersection of the 50 foot minimum guidance altitude (MGA) and the 2.5 degree glideslope angle which originates at the EL antenna phase center displaced to the runway centerline.

TABLE 2-2. BASIC NARROW SYSTEM ACCURACY (2σ) REQUIREMENTS AT THE ERROR WINDOW (SEE NOTES)

FUNCTIONAL ELEMENT	BIAS	PATH FOLLOWING NOISE	CONTROL MOTION NOISE	PATH FOLLOWING ERROR
Azimuth (a)	0.187°	0.078°	0.065°	0.200°
Elevation (b)	0.075°	0.087°	0.05°	0.115°
DME (c) DME (precision)	-	-	-	600 Ft. 100 Ft.
(a) Measured 8,000 feet from AZ antenna. (b) Measured on 2.5° glideslope at 50 foot MGA. (c) Measured 15,000 feet from AZ antenna.				

Path following error (PFE) is that portion of the angular error which can cause angular deviation of the aircraft from a predetermined course. It consists of bias and path following noise. It covers frequencies in the angle noise spectrum from 0 to 0.5 radian/second. Control motion noise (CMN) is that part of the angle noise spectrum from 0.3 to 10 radians/second for azimuth and from 0.5 to 10 radians/second for elevation. It affects the aircraft control surfaces and altitude and causes wheel and column motion. Path following noise (PFN) is that portion of the angle noise that can cause aircraft motion. Bias is a long-term error that cannot be reduced to zero by real-time calibration techniques.

In order to specify the BN system accuracy bounds at any point within the coverage, the error specifications at the error window are combined with the degradation functions allowed by Table 7-2 of the Functional Requirement Specification FAA-ER-700-07.

Table 2-3 shows the 2σ error bounds at the error window and the allowable error degradation away from the error window. Distance to the error window in Table 2-3 is measured from the AZ antenna. The linear error expressed in feet applies at the error window and for slant ranges less than the error window for landing aircraft. At slant ranges greater than the azimuth error window, the azimuth angular error bounds are constant with slant range, but vary with azimuth and elevation angle. For slant ranges and elevation angles greater than the elevation error window, the elevation error increases linearly with distance by a factor of 1.5 to 1 at a slant range of 20 nmi from the elevation antenna phase center and linearly with elevation angle from 2 degrees to 20 degrees. No degradation with azimuth angle is permitted.

TABLE 2-3. BASIC NARROW SYSTEM PATH FOLLOWING ERROR BOUNDS AT ERROR WINDOW, TYPE 2 EQUIPMENT

FUNCTIONAL ELEMENT	BIAS		PATH FOLLOWING NOISE (2 σ)		PATH FOLLOWING ERROR (2 σ)		GROUND DISTANCE TO ERROR WINDOW (a)	PATH FOLLOWING ERROR ALLOWABLE DEGRADATION (a)		
	FEET	DEGREE	FEET	DEGREE	FEET	DEGREE		WITH DISTANCE (c)	WITH AZ ANGLE	WITH EL. ANGLE
AZIMUTH (b)	26	0.187	11	0.078	28	0.20	8,000 FT.	NONE	2.1 IN ANGLE FROM 0° TO ±40° AZIMUTH	2.1 IN ANGLE FROM 0° TO 20° ELEVATION
ELEVATION (b)	1.4	0.075	1.7	0.087	2.2	0.115	10,000 FEET (MEASURED ON 2.5° GLIDESLOPE AT MGA)	1.5:1 IN ANGLE AT 20 NMI	NONE	3:1 IN ANGLE FROM 2° TO 20°
DME					600		15,000 FT.	NONE	NONE	NONE
DME (PRECISION)					100					

(a) DEGRADATIONS VARY LINEARLY BETWEEN THE LIMITS INDICATED.

(b) MINIMUM GUIDANCE ALTITUDE (MGA) - 50 FEET.

(c) DISTANCE IN SLANT RANGE FROM THE ELEVATION ANTENNA PHASE CENTER.

(d) MEASURED FROM AZ ANTENNA.

Table 2-4 shows the 2σ error bounds on control motion noise at the error window and how these error bounds are linearly degraded.

TABLE 2-4. BASIC NARROW SYSTEM CONTROL MOTION NOISE BOUNDS, TYPE 2 EQUIPMENT

FUNCTIONAL ELEMENT	CONTROL MOTION NOISE (2σ) (DEGREES)	ALLOWABLE DEGRADATION (a)		
		WITH DISTANCE	WITH AZIMUTH ANGLE	WITH ELEVATION ANGLE
AZIMUTH	0.065	1.2:1 FROM ERROR WINDOW TO 20 NMI	NONE	NONE
ELEVATION	0.05	1.4:1 FROM ERROR WINDOW TO 20 NMI	NONE	NONE

(a) DEGRADATIONS VARY LINEARLY BETWEEN THE LIMITS INDICATED.

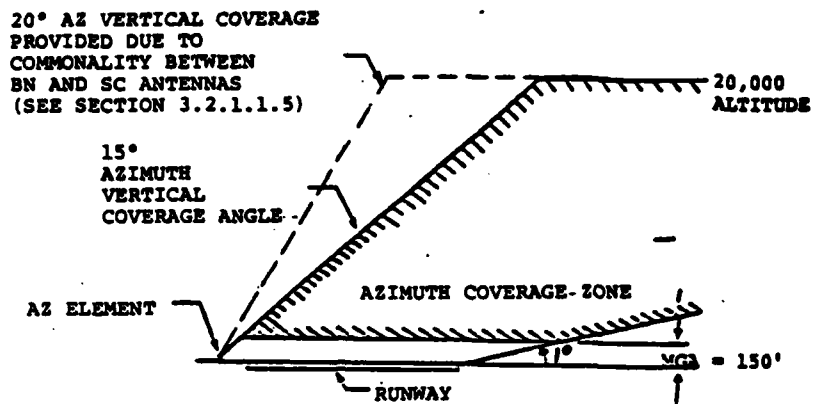
The control motion noise error bound is degraded by 1.2:1 and 1.4:1 for azimuth and elevation, respectively, at a slant range of 20 nmi from the elevation antenna phase center. No degradation with angle is permitted.

2.2.2 Small Community Ground Subsystem Requirements

The Small Community Ground Subsystem must provide approach guidance signals to aircraft within the volume defined in Table 2-5 and shown in Figures 2-3 and 2-4.

TABLE 2-5. SMALL COMMUNITY GROUND SUBSYSTEM COVERAGE REQUIREMENTS

FUNCTIONAL ELEMENT	MAX. ALTITUDE AGL (FT)	MAX. RANGE FROM EL (NM)	HORIZONTAL COVERAGE (DEG)		VERTICAL COVERAGE (DEG)	
			SYSTEM	PROPORTIONAL GUIDANCE	SYSTEM	PROPORTIONAL GUIDANCE
AZIMUTH (AZ)	20,000	15	±40	±10	1 - 15	1 - 15
ELEVATION (EL)			±10	±10	1 - 15	1.9 - 10.67



a. VERTICAL COVERAGE

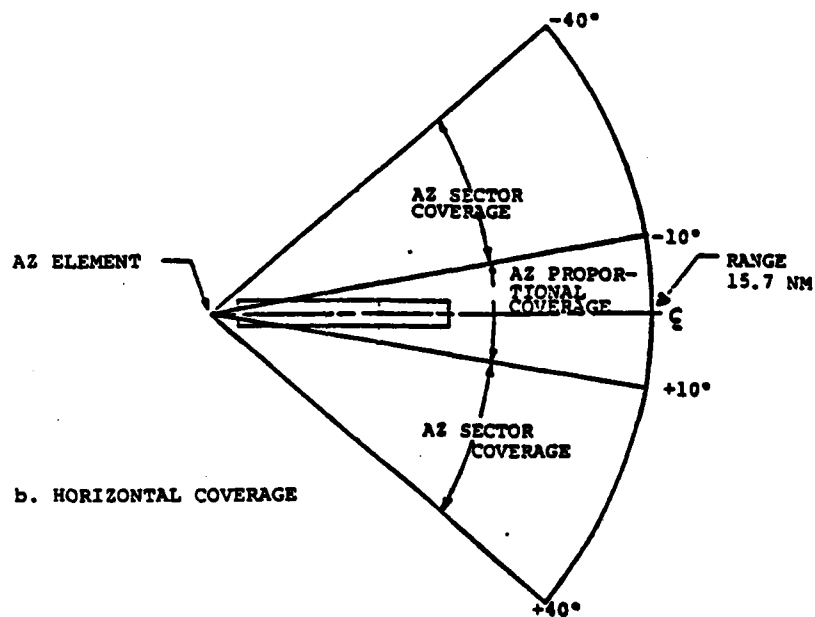


FIGURE 2-3. SMALL COMMUNITY AZ SUBSYSTEM COVERAGE REQUIREMENTS

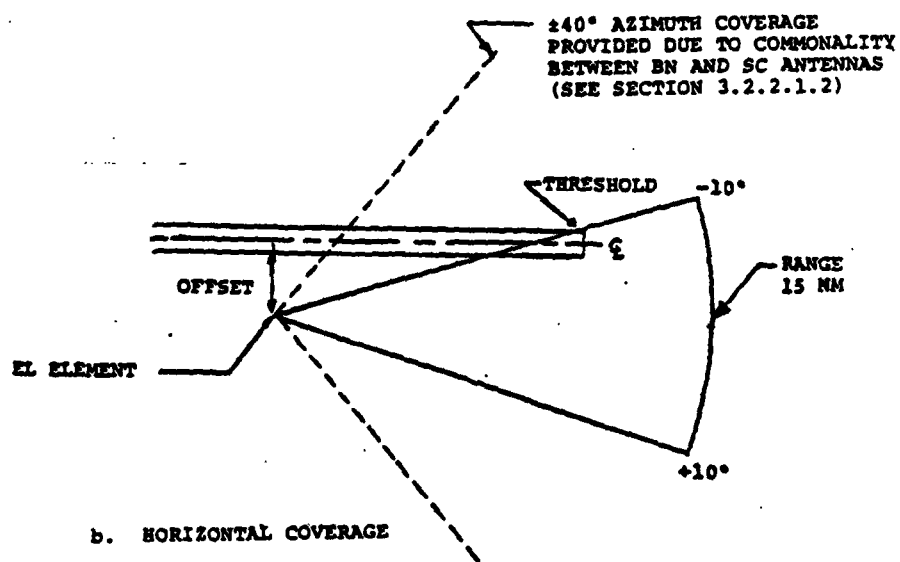
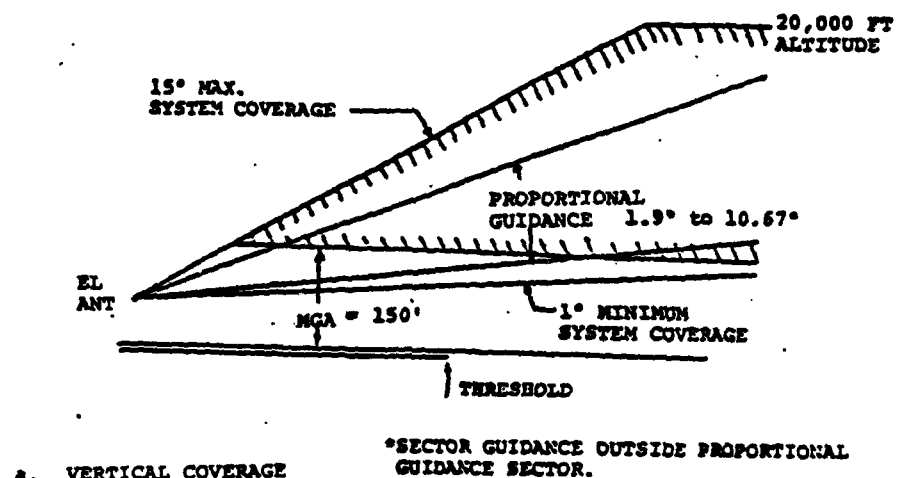


FIGURE 2-4. SMALL COMMUNITY EL SUBSYSTEM COVERAGE REQUIREMENTS

The Small Community system error window accuracies (ground, airborne, and propagation) are shown in Table 2-6. The error specifications at the error window, combined with the degradation allowed by Table 7-3 of the Functional Requirements Specification FAA-ER-700-07 are shown in Table 2-7.

TABLE 2-6. SMALL COMMUNITY SYSTEM ACCURACY REQUIREMENTS AT THE ERROR WINDOW, (SEE NOTES)

FUNCTIONAL ELEMENT	BIAS (DEGREES)	PATH FOLLOWING NOISE (DEGREES)	CONTROL MOTION NOISE (DEGREES)	PATH FOLLOWING ERROR (DEGREES)
Azimuth (a)	0.29	0.15	0.1	0.33
Elevation (b)	0.108	0.12	0.1	0.162
(a) Measured 10,000 Ft. from AZ antenna. (b) Measured at 150 foot MGA on 2.5° glide slope.				

Table 2-7 shows the 2σ error bounds at the error window and how the errors are degraded away from the error window. The minimum guidance altitude above threshold is 150 feet for the Small Community system. The elevation window is located 7,436 feet from the azimuth antenna phase center measured along runway centerline. This position is found by determining the point where the 2.5 degree glide slope reaches a height of 150 feet above threshold. The glide slope passes through the elevation antenna phase center displaced to runway centerline.

TABLE 2-7. SMALL COMMUNITY PATH FOLLOWING ERROR BOUNDS,
TYPE 1 EQUIPMENT

FUNCTIONAL ELEMENT	BIAS		PATH FOLLOWING NOISE (2 σ)		PATH FOLLOWING ERROR (2 σ)		GROUND DISTANCE TO ERROR WINDOW ^(b)	PATH FOLLOWING ERROR ALLOWABLE DEGRADATION ^(c)		
	FEET	DEGREE	FEET	DEGREE	FEET	DEGREE		WITH DISTANCE ^(d)	WITH AZ ANGLE	WITH EL ANGLE
AZIMUTH ^(a)	50	0.29	26	0.15	56	0.33	10,000 FEET	LINEARLY TO 0.4° AT 20 NM	2:1 IN ANGLE FROM 0° TO ± 10° AZIMUTH	2:1 IN ANGLE FROM 0° TO 15°
ELEVATION ^(a)	6.1	0.100	6.8	0.12	9.2	0.162	7635 FEET (MEASURED ON 2.9° GLIDESLOPE AT MCA)	1.5:1 AT 20 NM	NONE	3:1 IN ANGLE FROM 2° TO 20°

(a) DEGRADATIONS VARY LINEARLY BETWEEN THE LIMITS INDICATED.

(b) MINIMUM GUIDANCE ALTITUDE (MCA) = 150 FEET.

(c) DISTANCE IN SLANT RANGE FROM THE ELEVATION ANTENNA PHASE CENTER.

(d) MEASURED FROM AZ ANTENNA.

PL-000

Table 2-8 shows the 2 σ error bounds on control motion noise and how these error bounds are degraded linearly for distances greater than the error window.

TABLE 2-8. SMALL COMMUNITY SYSTEM CONTROL MOTION
NOISE BOUNDS, TYPE 1 EQUIPMENT

FUNCTIONAL ELEMENT	NOISE (2 σ) (DEGREES)	ALLOWABLE DEGRADATION ^(a)		
		WITH DISTANCE ^(b)	WITH AZIMUTH ANGLE	WITH ELEVATION ANGLE
AZIMUTH	0.1	2:1 FROM ERROR WINDOW TO 20 NM	NONE	NONE
ELEVATION	0.1	2:1 FROM ERROR WINDOW TO 20 NM	NONE	NONE

(a) DISTANCE IS SLANT RANGE FROM THE ELEVATION ANTENNA PHASE CENTER.

(b) DEGRADATIONS VARY LINEARLY BETWEEN THE LIMITS INDICATED.

2.2.3 Airborne Equipment Requirements

2.2.3.1 Basic Narrow A/B Subsystem - The airborne equipment consists of six functional units:

- a. Control Panel
- b. AZ/EL Angle Guidance Receiver/Decoder
- c. DME Interrogator/Receiver
- d. DME/Range Rate Indicator
- e. Auxiliaty Data Display
- f. Antennas and Related Switches

The 2σ accuracies for each guidance function are given in Table 2-9.

TABLE 2-9. 2σ ACCURACY REQUIREMENTS OF BN
AIRBORNE EQUIPMENT

FUNCTION	BIAS (DEGREES)	CONTROL MOTION NOISE (DEGREES)	PATH FOLLOWING ERROR (DEGREES)
AZIMUTH	0.017	0.007	0.018
ELEVATION	0.017	0.007	0.018
DME (prec)	-	-	76 FT. (a)

- (a) 2σ value when measured within 5 miles of transponder. RSS of 60 Ft. Bias and 2 Rad/Sec Noise, 46 Ft. Multi-path error, and a 10-FT. garbled pulse (3 sec. interval) contribution.

The aircraft antenna(s) must provide 360 degree coverage in azimuth, at least ± 30 degree in roll, and at least ± 20 degree in pitch.

The receiver sensitivity must be such that it is capable of full lock-on with the following signal levels at the antenna terminals:

- a. Function Preamble and Auxiliary Data Signals -100 dBm
- b. Left and Right Clearance Signals -100 dBm
- c. Scanning Beam Signals -96 dBm
- d. DME Interrogator Signal -83 dBm

2.2.3.2 Small Community A/B Subsystem - The 2σ accuracies for the two guidance functions are given in Table 2-10.

TABLE 2-10. 2σ ACCURACY REQUIREMENTS OF SC AIRBORNE EQUIPMENT

FUNCTION	BIAS (DEGREES)	CONTROL MOTION NOISE (DEGREES)	PATH FOLLOWING ERROR (DEGREES)
AZIMUTH	0.05	0.05	0.051
ELEVATION	0.05	0.05	0.051

The aircraft antennas must provide coverage of at least ± 90 degrees in azimuth, at least ± 30 degrees in roll, and at least ± 15 degrees in pitch.

The receiver sensitivity must be such that it is capable of full lock-on with the following signal levels at the antenna terminals:

- a. Function Preamble and Auxiliary Data Signals -96 dBm
- b. Left and Right Clearance Signals -96 dBm
- c. Scanning Beam Signals -92 dBm

2.3 BASIC NARROW GROUND SUBSYSTEM

2.3.1 General

The Basic Narrow (BN) ground subsystem is composed of three functional elements:

- approach azimuth element (AZ)
- approach elevation element (EL)
- distance element (DME)

These elements are physically contained in two major equipment groups, the AZ/DME equipment group and the EL equipment group. The AZ/DME and EL equipment groups each consists of an electronics shelter, an antenna case, and a field monitor. A high level system block diagram is shown in Figure 2-5.

The BN, at the time of testing, was deployed at runway 13/31 at NAFEC. A plan view of the airport is shown in Figure 2-6. The AZ and DME equipments were located at the southeast end of the runway, and the EL equipment was located at the northwest end. The locations of the AZ/DME equipment and EL equipment relative to the runway are shown in Figure 2-7.

An artist's rendition of the AZ/DME equipments is shown in Figure 2-8. This drawing shows, in addition to the relative physical separations, the location of the various antennas employed in the AZ/DME equipment. The major components contained within the antenna case and the equipment shelter are listed in Table 2-11.

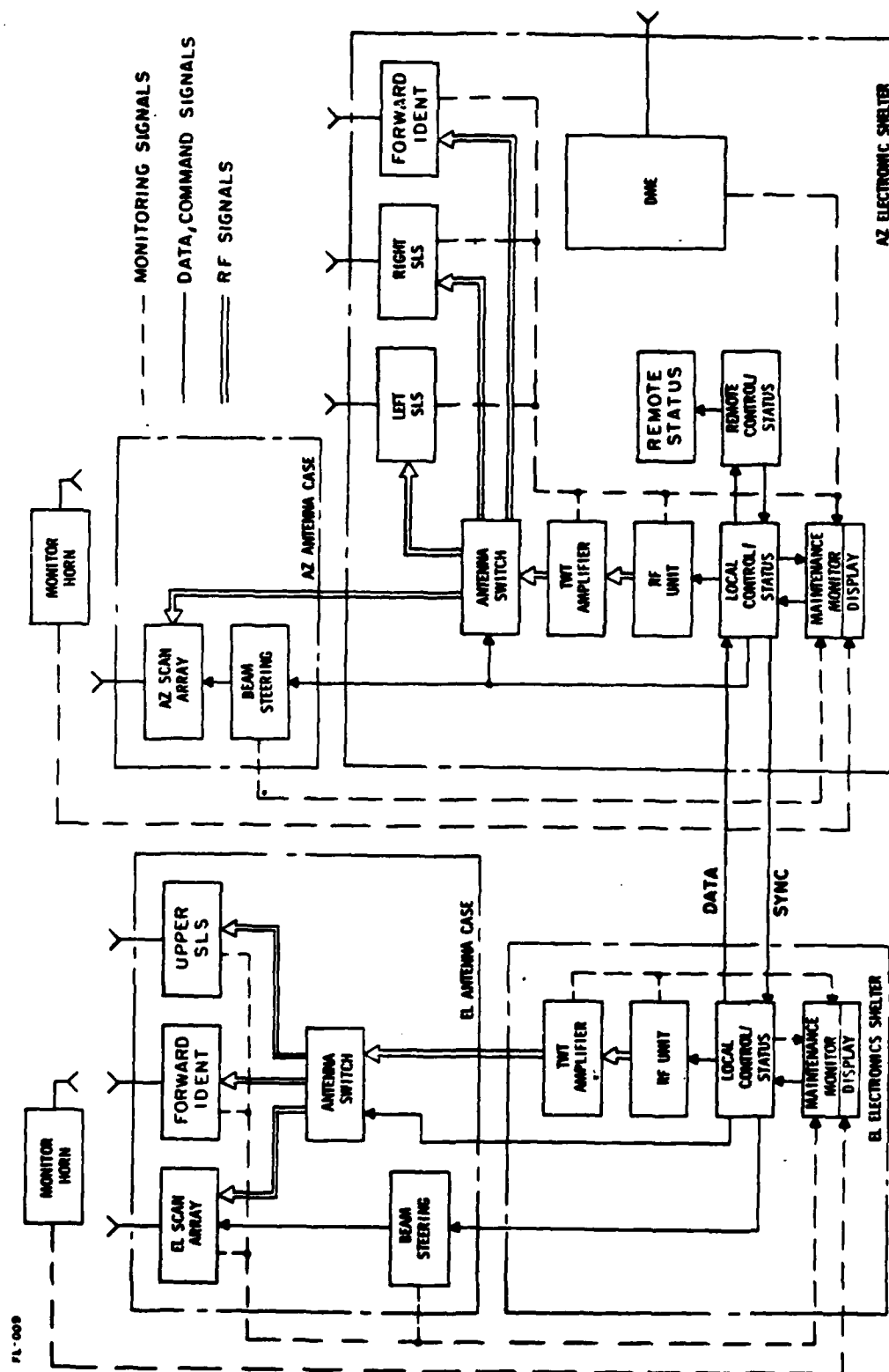


FIGURE 2-5. BASIC NARROW SYSTEM BLOCK DIAGRAM

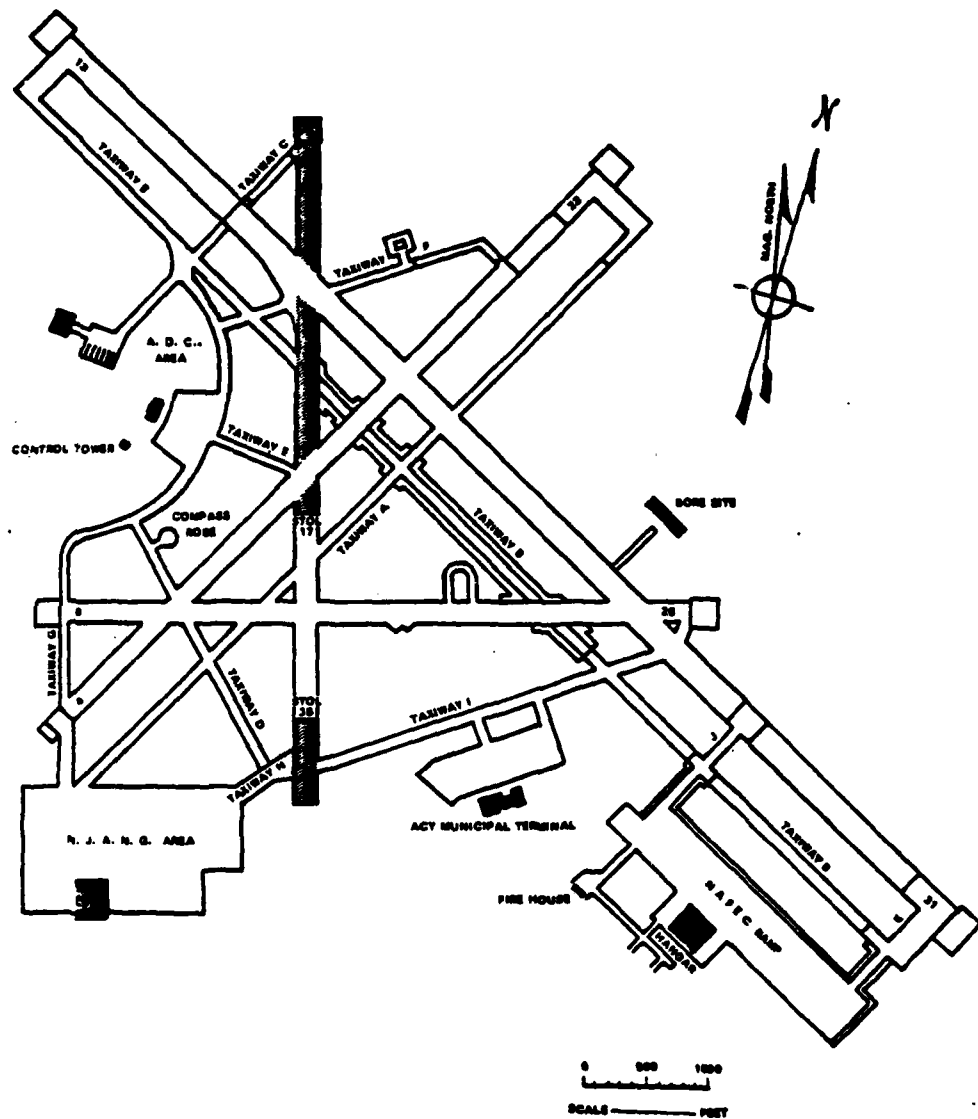


FIGURE 2-6. NAFEC/ATLANTIC CITY AIRPORT,
ATLANTIC CITY, NEW JERSEY

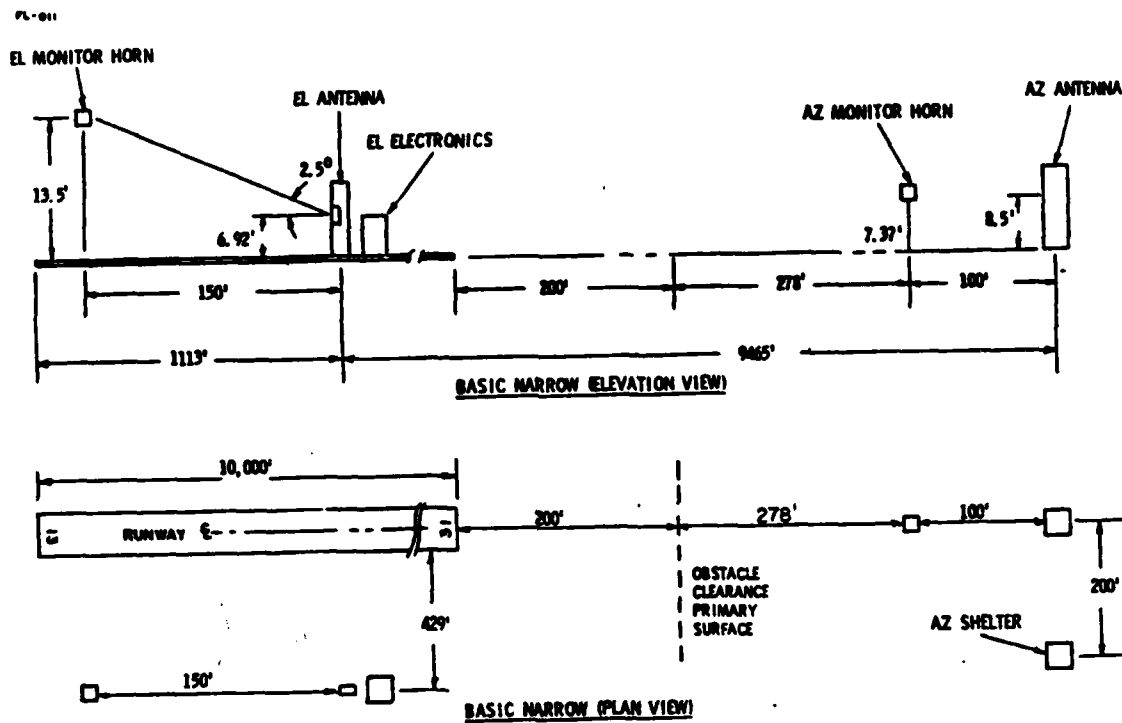


FIGURE 2-7. BASIC NARROW EQUIPMENT CONFIGURATION ON RUNWAY 13/31

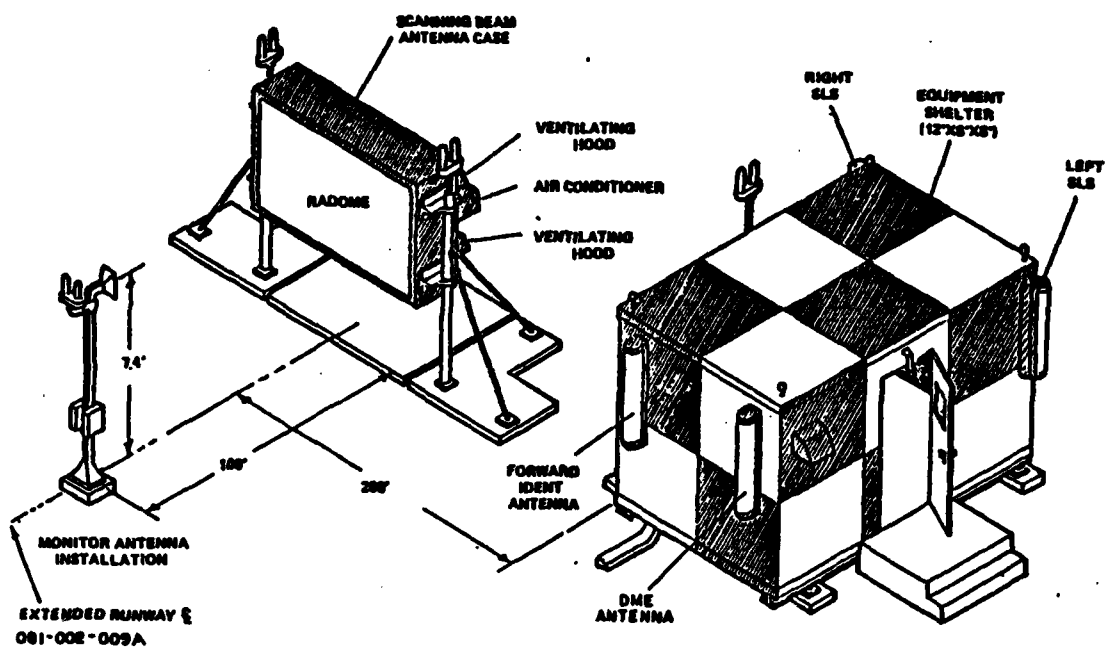


FIGURE 2-8. BASIC NARROW AZIMUTH/DME EQUIPMENT

TABLE 2-11. MAJOR COMPONENTS OF
BASIC NARROW AZ SUBSYSTEM

AZ Equipment Shelter

Ground angle electronics cabinet

TWT amplifier

RF unit (C-band exciter, bi-phase modulator)

Local control/status

Maintenance monitor

Antenna selector switch

DME cabinet and antenna

Auxiliary electronics cabinet

Remote control/status

Remote Status

Maintenance display

Forward Ident antenna

Left SLS antenna

Right SLS antenna

AZ Antenna Case

Azimuth scanning beam antenna

Beam steering electronics

Fine scan modulator

Rotman lens

RF scan switches

Figure 2-9 is a composite of the azimuthal coverage from the AZ site. Included are the scanning beam coverage and patterns of the forward ident and the left and right rear sidelobe suppression antennas. These patterns are described in detail in paragraph 3.2.1. The DME antenna pattern is described in paragraph 3.2.1.11.

A sketch of the EL equipment is shown in Figure 2-10. The major components contained in the antenna case and equipment shelter are listed in Table 2-12.

TABLE 2-12. MAJOR COMPONENTS OF BASIC NARROW EL SUBSYSTEM

EL Equipment Shelter

Ground angle electronics cabinet

TWT Amplifier

RF unit (C-band exciter, bi-phase modulator)

Local control/status

Maintenance Monitor

Auxiliary electronics cabinet

Maintenance display

EL Antenna Case

Elevation antenna

Beam steering electronics

Fine scan modulator

Rotman lens

RF scan switches

Antenna selector switch

Forward ident antenna

Upper SLS antenna

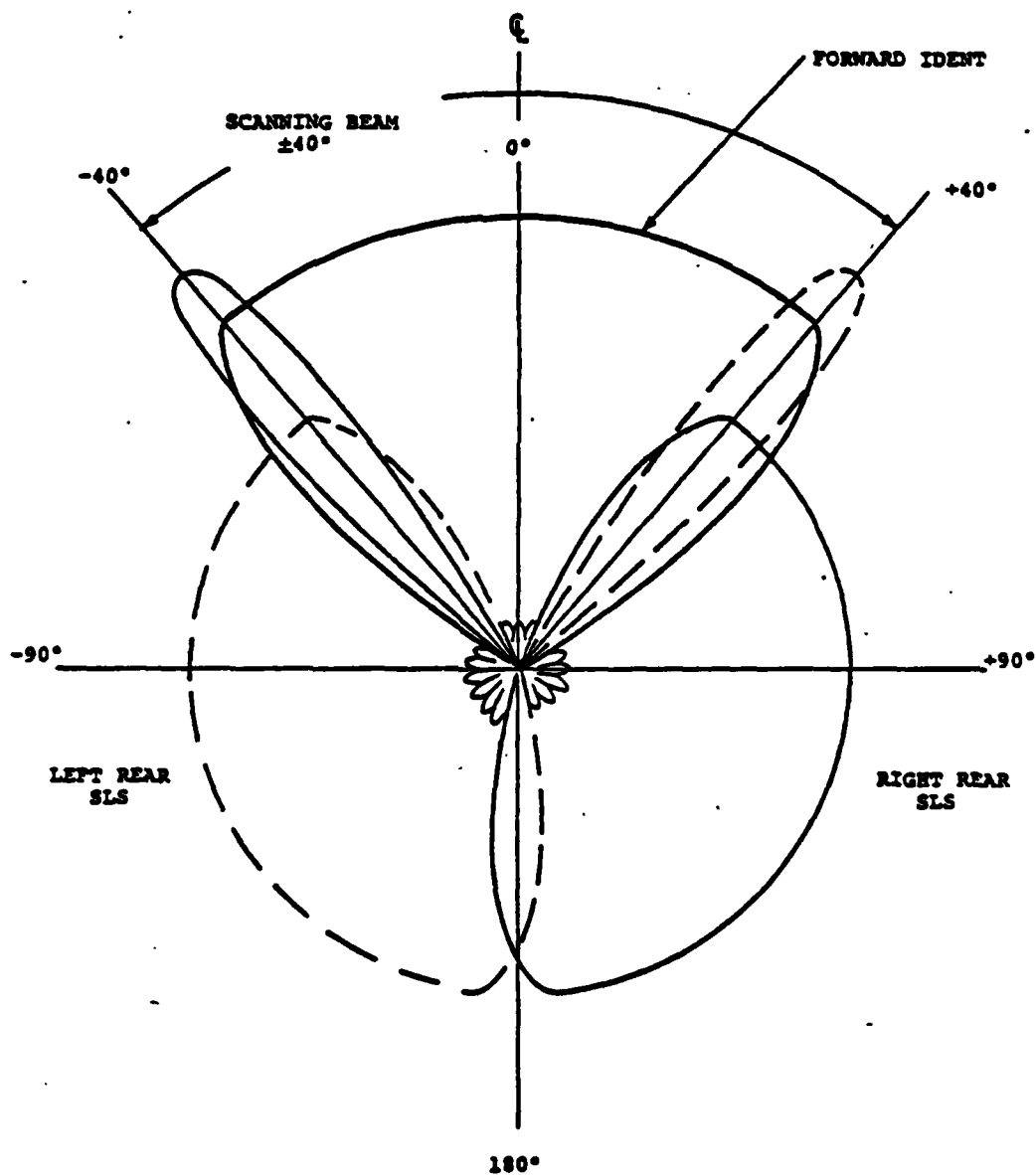


FIGURE 2-9. AZIMUTH COVERAGE OF BASIC NARROW AZ SUBSYSTEM

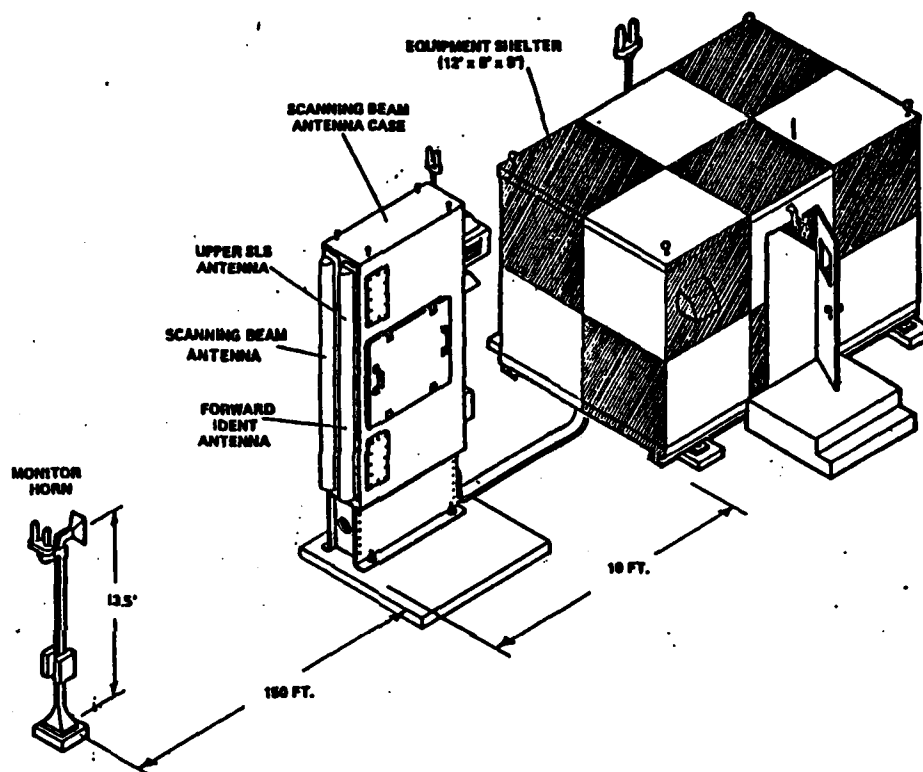


FIGURE 2-10. BASIC NARROW ELEVATION EQUIPMENT

Figure 2-11 is a composite of the vertical coverage from the EL site. Included are the elevation scanning beam coverage and the forward ident and upper sidelobe suppression patterns. These patterns are described in detail in paragraph 3.2.2.

The prime power requirements for the BN ground subsystem are listed in Table 2-13.

TABLE 2-13. BN PRIME POWER REQUIREMENTS (WATTS)

FUNCTION	AZ	EL	TOTAL
Electronics	1513(a)	624	2137
Environmental	8532	8712	17244
Deicing	7164	2292	9456
Lighting	1512	1332	2844
Convenience (b)	6600	6600	13200
TOTALS	25321	19560	44881

(a) Includes 500 W for DME and 83 W for Remote Control/Status and Remote Status.

(b) Assumes utility outlets fully loaded.

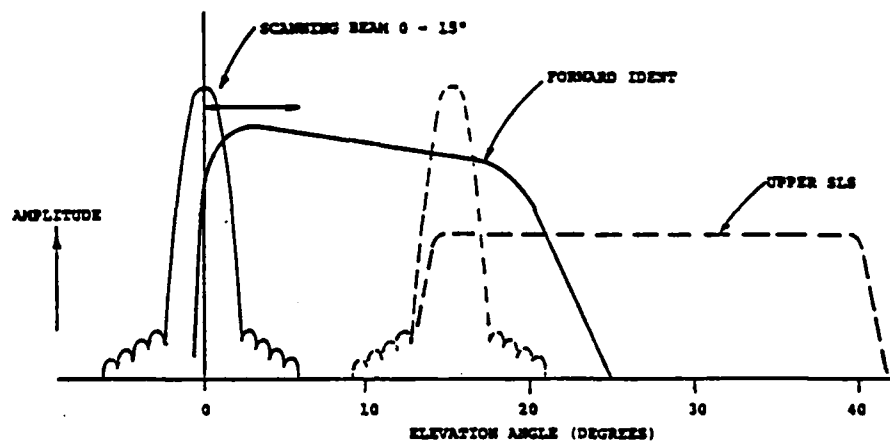


FIGURE 2-11. ELEVATION COVERAGE OF BASIC NARROW EL SUBSYSTEM

2.3.2 Subsystem Performance

This section describes the system features and performance of the BN ground subsystem. Included are the subsystem error budget, accuracy goals, and antenna scan angles, beamwidths, and gains. A more complete description of the antenna patterns is given in section 3.1.

2.3.2.1 Accuracy Goals And Error Budget - Although the BN system must meet the accuracy specifications defined in paragraph 2.2.1, the partitioning of the accuracy requirements among the ground subsystem and the airborne equipment is done in such a manner that individual subsystem specifications are achievable, while meeting the overall system requirements.

Table 2-14 illustrates the partitioning of the BN system accuracy requirements among the ground subsystem, the airborne equipment, and multipath effects. The ground subsystem and airborne equipment accuracies are taken from FAA-ER-700-01; the multipath effects were estimated by assigning to the multipath allotment that error which would cause the RSS of the ground, airborne, and multipath errors to add up to the system error.

The errors assigned to the ground and multipath sources provide the basis for defining system design specifications and budgeting system tolerances. These are discussed in the next section.

2.3.2.2 System Design Parameters - Since MLS is an air-derived system, performance is dictated almost entirely by the characteristics of the scanning beam and the airborne receiver. Although the actual multipath environment cannot be controlled through system design, the multipath effects can be minimized by judiciously specifying the radiated patterns and applying known circuit techniques in the receiver. Considering only the ground system at this point, the scanning beam characteristics are determined completely by the antenna with its associated beam steering. Table 2-15 lists the BNAZ and BNEL antenna specifications. The specifications marked with an asterisk are defined in the FAA-ER-700 series of specifications. The remaining specifications are based on and are consistent with meeting the requirements listed in Table 2-14.

TABLE 2-14. ALLOCATION OF BASIC NARROW
SYSTEM ERRORS (2σ)

AZIMUTH ELEMENT

Error Source	Bias (Deg.)	PFN (Deg.)	CMN (Deg.)	PFE (Deg.)
Ground	0.130	0.001	0.016	0.130
Airborne	0.017	0.003	0.009	0.017
Multipath	0.133	0.077	0.062	0.151
System	0.187	0.078	0.065	0.200

ELEVATION ELEMENT

Error Source	Bias (Deg.)	PFN (Deg.)	CMN (Deg.)	PFE (Deg.)
Ground	0.071	0.001	0.012	0.0725
Airborne	0.017	0.002	0.007	0.017
Multipath	0.017	0.086	0.046	0.098
System	0.075	0.087	0.050	0.115

DME ELEMENT

Error Source	PFE (Ft.)
Ground	46
Airborne	76
Multipath	46
System	100

TABLE 2-15. BASIC NARROW GROUND SUBSYSTEM
ANTENNA SPECIFICATIONS

PARAMETER	AZ	EL
Scanning Beam:		
3 dB beamwidth (boresight)	2° +0.1°	1.5° +0.1°
15 dB beamwidth (max.)	4.1°	3.1°
*Lateral coverage	+40°	+40°
*Vertical coverage	1 to 20°	1 to 15°
*Scan guidance coverage	1 to 20° (vertical) +40° (lateral)	+40° ^c (lateral) 1.90° - 10.67° (vertical)
Sidelobe level (max.)	-20 dB	-20 dB
Beam step size (max.)	0.2°	0.15°
Switching rate (max.)	1 µsec/ transition	1 µsec/ transition
*Scan rate	20,000 deg/sec	20,000 deg/sec
Overscan	1/2 beamwidth	1/2 beamwidth
Net Gain (min.)	23 dBi	20 dBi
*Polarization	vertical	vertical
Underside cutoff (min.)	6 dB/deg at 0° elevation	NA
*To-FRO scans/second	13.5	40.5
Lateral gain variation	NA	-3 dB @ +20° -7 dB @ +40°
ERP (scanning beam) (min.)	45.1 dBm	44.4 dBm
ERP (SLS) (min.)	35.1 dBm	34.5 dBm
ERP (Forward Ident) (min.)	41.1 dBm	40.4 dBm
ERP (DME) (min.)	43.0 dBm	NA

*Defined by FAA-ER-700 series documents

2.3.3 Power Budget

The power budget for the Basic Narrow system is shown in Table 2-16. Power budgeting for both the AZ and EL subsystems and the DME ground-to-air (G/A) and air-to-ground (A/G) are shown. The losses are summarized in the last four rows of the table. The first of these rows is the minimum power at the aircraft under worst-case conditions. This is simply the arithmetic sum of the losses (gains) in the body of the table. These losses (gains) are maximum (minimum) values. The next line is the specified minimum power at the aircraft per FAA-ER-700-01. The third row is the difference of the first two rows and shows the system power margin for worst-case conditions. The last line is an RSS estimate of the minimum power margin, i.e., the "expected" minimum power margin. This is obtained by taking the RSS (in power) of the items marked with an asterisk and adding this algebraically to the remaining losses (gains). The eleven loss (gain) quantities are defined below.

The transmitter power is obtained from the nominal 20 W output for the AZ and EL subsystems, the 100 W peak output for the ground DME, and the 125 W peak output for the airborne DME.

The cable losses for the AZ and EL include all losses from the TWTA output to the input of the antenna case. For the DME (G/A) it includes losses from the transmitter to the DME antenna terminals. The cable loss for the DME (A/G) was obtained from FAA-ER-700-01 (Appendix E) and represents the loss allotment from the antenna to the first electronics.

The component losses for the AZ and EL scanning beams include all cables and component losses from the antenna case input to the antenna input. The component loss for the DME includes the multiplexer.

The antenna gains for the AZ and EL equipment are the measured gains obtained at the input to each antenna; as such, it includes all losses within the antenna structure. The gain for the DME antenna is the minimum specified gain as stated by the manufacturer.

The AZ and EL coverage losses are the worst-case antenna gain degradations within the defined coverage sectors. Typically, these occur at the extremes of the coverage, thus the rationale for including these losses in the RSS calculation is that the average loss during a scan will be less than the worst-case value given.

The monitor limit loss is the allowable 3 dB decrease in transmitter output before a monitor system alarm is given.

TABLE 2-16. POWER BUDGET FOR THE BASIC NARROW GROUND SUBSYSTEM

	AZIMUTH		ELEVATION		DME	
	ARRAY	PREAMBLE	ARRAY	PREAMBLE	G/A	A/G
Transmitter Power	43.0	43.0	43.0	43.0	50.0	51.0
Cable Losses	-2.0	-2.0	-2.0	-2.0	-1.5	-3.0
Component Losses	-4.1	-0.9	-2.4	-2.4	-1.5	-1.5
Antenna Gain (c)	22.6	13.8	20.4	14.2	9.5	9.5
*Az Coverage Loss (b)	-1.5	-1.5	-7.0	-1.5	-3.0	-3.0
*EL Coverage Loss (b)	-5.6	-5.6	-0-	-5.6	-3.0	-3.0
Monitor Limit Loss	-3.0	-3.0	-3.0	-3.0	-3.0	-3.0
Propagation Loss (d)	-138.6	-138.6	-138.0	-138.0	-125.3	-125.3
Atmospheric Loss	-0.3	-0.3	-0.3	-0.3	-0.2	-0.2
*Rain Loss	-2.2	-2.2	-2.1	-2.1	-0-	-0-
*Polarization Loss	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
Min. Power at A/C	-92.2	-97.8	-91.7	-98.2	-78.5	-79.0 (a)
Spec. Power at A/C	-96.0	-100.0	-96.0	-100.0	-83.0	-85.0 (a)
Minimum Margin	3.8	2.2	4.1	1.8	4.5	6.0
RSS Margin	7.4	5.8	6.4	5.3	6.7	8.2

Power in dBm; gains, losses, and margins in dB.

*RSS of these terms gives RSS margin

(a) Power at ground antenna terminals.

(b) Worst-case coverage loss, +40° Azimuth, 1° to 20° Elevation.

(c) Assumes 0 dBi gain aircraft antenna.

(d) Assumes EL distance = 20 NM; AZ/DME distance = 21.6 NM

Propagation loss is based on the equation:

$$\text{Loss}_{\text{Prop}} = 20 \log \frac{4\pi R}{\lambda} \text{ dB}$$

where the range for the EL equipment is 20 nmi, and that for the AZ and DME equipment is 21.6 nmi. For the scanning beams, a frequency of 5090 MHz was used and for the DME, a frequency of 1095 MHz was used.

The atmospheric attenuation loss is calculated from:

$$\text{Loss (C-Band)} = 0.041 \text{ dB/nmi}$$

$$\text{Loss (L-Band)} = 0.0104 \text{ dB/nmi.}$$

The rain loss is calculated assuming a 50 mm/hr rainfall for the first 5 nmi (0.185 dB/nmi) and 25 mm/hr for the remaining range distance (0.074 dB/nmi) for the AZ and EL equipment. The rain loss for the L-Band DME is negligible.

The polarization loss is taken as 0.5 dB maximum and is due primarily to attitude changes in the aircraft. Since the rain and polarization losses vary significantly from the worst-case values under typical conditions, these two losses are also included in the RSS total.

It can be seen from Table 2-16 that there is a minimum of 5.3 dB margin for the RSS case. Even under worst-case conditions, the margin is at least 1.8 dB.

2.3.4 Signal Format

2.3.4.1 General - The BN ground subsystem transmits angle guidance and data signals. Supplementary to the BN system, but not an inherent part of the angle system, range-to-touchdown information is obtained through conventional DME techniques. The DME equipment operates at L-band and is independent of the C-band angle equipment. This section will discuss only the angle equipment signals.

The signal format is based on time division multiplexing (TDM) wherein each angle guidance function is transmitted in sequence and all are transmitted on the same frequency. The multiplexing of the various angle functions is the scan format. The scan format in conjunction with the detailed parameters of each time slot comprise the signal format.

The MLS angle system can operate over any of 200 channels, spaced 300 kHz apart, over the frequency range 5031.0 to 5090.7 MHz.

The Microwave Landing System utilizes a repetition cycle of 592 ms, as shown in Figure 2-12A. Each cycle consists of eight sequences of different duration. Advantage is taken of this variable duration to transmit auxiliary data. The resulting jittered signal format precludes accidental synchronization from interfering sources.

Each sequence consists of three parts, denoted (A, B, C) in Figure 2-12B. For every sequence, parts A and B are 31 and 22.8 ms, respectively. The length of part C is variable and used to extend the sequence durations to the values given in Figure 2-12A. Part A (Figures 2-12C and D) contains EL and AZ function signals, part B contains EL function signals only (even numbered sequences also contain Basic Data Word #1), and part C contains EL function signals only (sequence #3 also contains Basic Data Word #2). Thus, the AZ and EL data rates are 13.5 and 40.5 Hz, respectively.

2.3.4.2 Elevation Element - The details of the EL signal format are shown in Figure 2-13. The timing is expressed in clock pulses which occur every $66\frac{2}{3}$ μ s (15 kHz rate). The EL signal format occurs at the beginning of each frame and lasts 78 clock pulses (5.2 ms). The preamble lasts 20 clock pulses ($1\frac{1}{3}$ ms) and contains 20-bits of binary digital data that is encoded by means of Differential Phase Shift Keying (DPSK) of the RF carrier. The preamble contains the RF acquisition guard band, Barker code, Function ID, and minimum selectable glide slope. The guard band provides RF carrier acquisition by the DPSK decoding circuits. The Barker code is used for data synchronization. The function identification provides identity of the transmitter (AZ, EL, Flare, etc.). The minimum selectable glide slope defines the minimum safe facility glide slope and is used by the receiver to prohibit selection of a lower, unsafe glide slope.

The upper sidelobe suppression (SLS) transmission occurs from clock pulse 20 to 22. The scanning beam "TO" scan begins at clock pulse 33 and ends at 45. Clock pulse 48 is the midpoint of the TO/FRO scan. The "FRO" scan extends from clock pulse 51 through 63. Clock pulses 74 and 78 indicate the end of the airborne function time and the ground elevation time frame, respectively.

Basic data word #2 is transmitted by the EL subsystem during part C of sequence 3.

2.3.4.3 Azimuth Element - The details of the AZ signal format are shown in Figure 2-14. The timing here is also expressed in clock pulses. The AZ signal format occurs only in part A of each sequence and lasts 237 clock pulses (15.8 ms). The preamble lasts 25 clock pulses and has 25-bits of DPSK data containing the RF guard band, Barker code, function ID, facility Morse code ID,

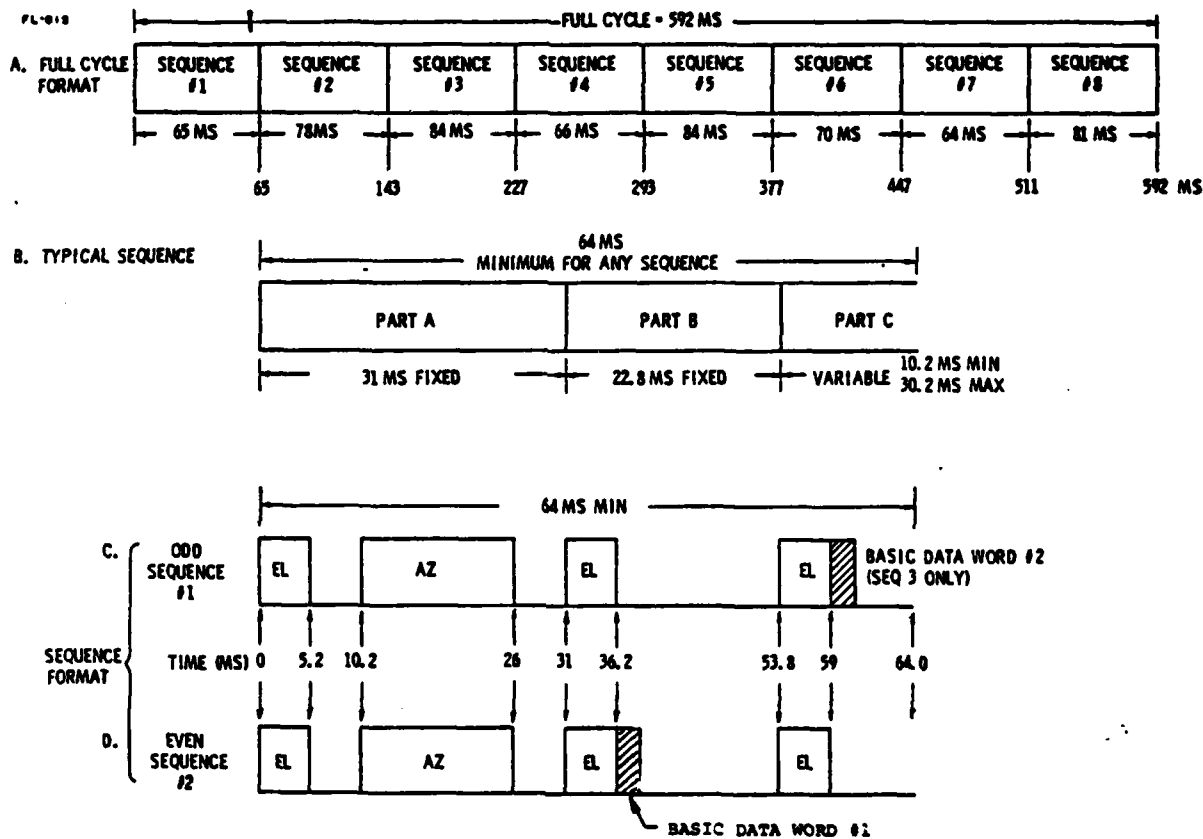


FIGURE 2-12. BASIC NARROW AND SMALL COMMUNITY SIGNAL FORMAT

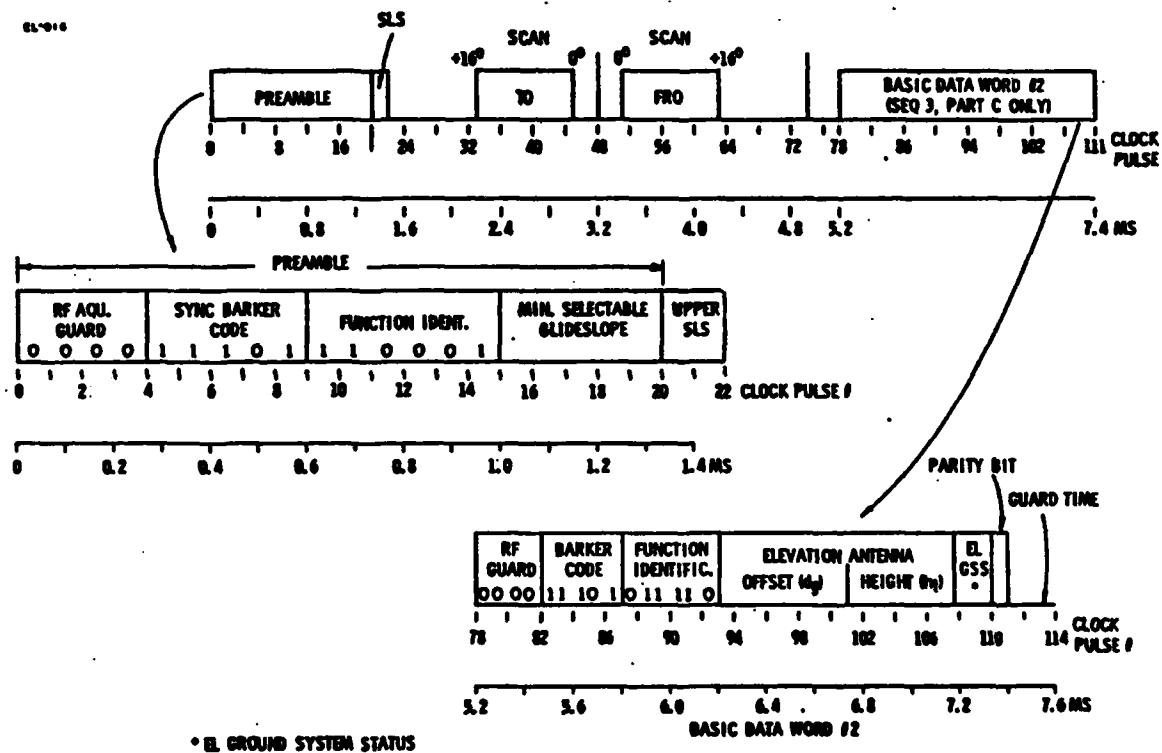


FIGURE 2-13. ELEVATION FUNCTION FORMAT, BASIC NARROW AND SMALL COMMUNITY

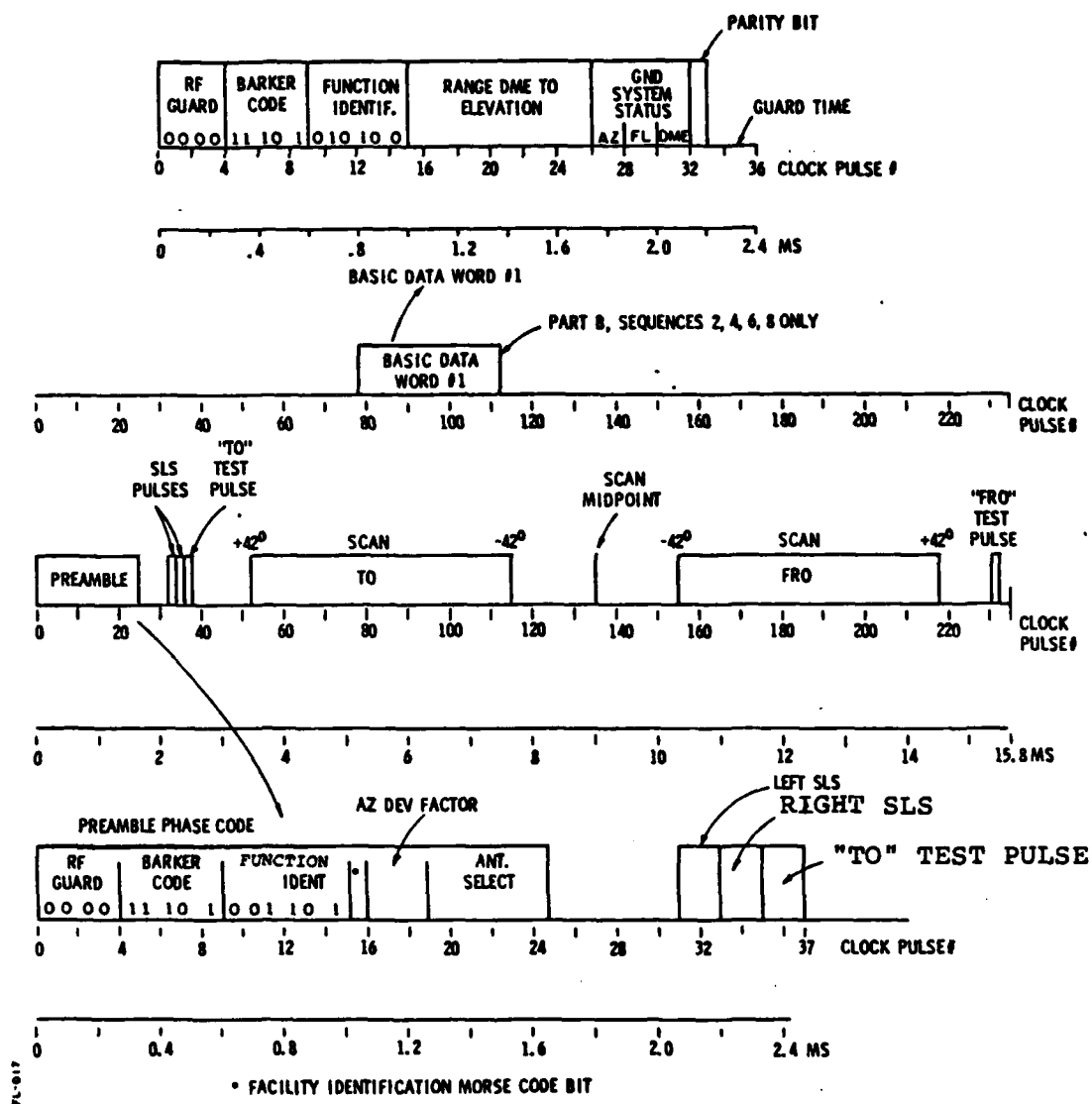


FIGURE 2-14. BASIC NARROW AZ SIGNAL FORMAT

azimuth deviation scale factor, and airborne antenna select pulse. The guard band, Barker code, and function ID are the same as for the EL signal format, except for the code difference in the ID. The facility identification Morse code bit is used to turn on and turn off an audio tone in the aircraft, thereby generating a Morse code signal for facility ID. The azimuth deviation scale factor is used to convert angle deviation information to distance deviation information (distance from runway centerline at threshold). The airborne antenna selection signal is used by the aircraft receiver to make antenna gain comparisons for selecting the antenna with the highest gain.

The left and right sidelobe suppressions occur from 31 to 33 and from 33 to 35 clock pulses, respectively. The TO scan test signal occurs from 35 to 37 clock pulses. The TO scan test pulse is a pulse of controlled shape (for radiation interference control) and is used with the precisely spaced FRO test pulse to provide an end-to-end test of the receiver. The AZ TO scan occurs from 52 to 115 clock pulses. The midpoint of the TO/FRO scan occurs at 134.5 clock pulses. The FRO scan extends from 154 to 217 clock pulses. The TO and FRO scans are centered (0 degree scan angle) at 83.5 and 185.5 clock pulses, respectively. The FRO test pulse occurs between 232 and 234 clock pulses.

During part B of sequences 2, 4, 6, and 8, basic data word #1 is transmitted from the AZ site (see Figure 2-12).

Referring to Figure 2-12, up to 12 auxiliary data words of 64-bits each (1 in sequence 8, 2 in sequence 2, and 3 in each of sequences 3, 5, and 8) can be transmitted from the AZ site during a signal format cycle (592 msec) using the variable length, unused time periods at the end of the sequences. The auxiliary data format is shown in Figure 2-15. Two data formats, Figure 2-16, are provided: one for digital data and one for ASCII character data. The address defines the contents of the auxiliary data word.

2.3.5 Monitoring

2.3.5.1 General - The basic purpose of the monitoring subsystem is to provide assurance that the system is performing properly by reliably indicating the status of all key system performance parameters. If a failure is detected, the monitor must initiate site shutdown in order to minimize the radiation of erroneous guidance signals.

The approach taken to assure a high degree of system integrity within reasonable economic constraints is to employ a single-point executive field monitor and a carefully selected group of internal executive monitors. The single point field

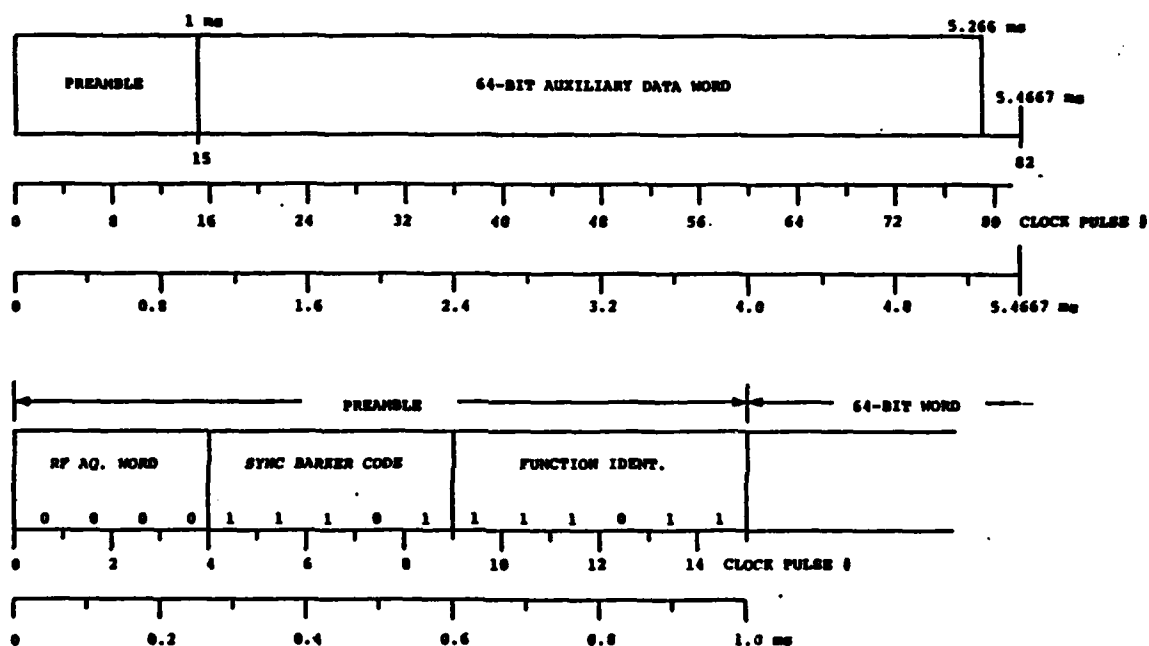


FIGURE 2-15. AUXILIARY DATA FUNCTION FORMAT

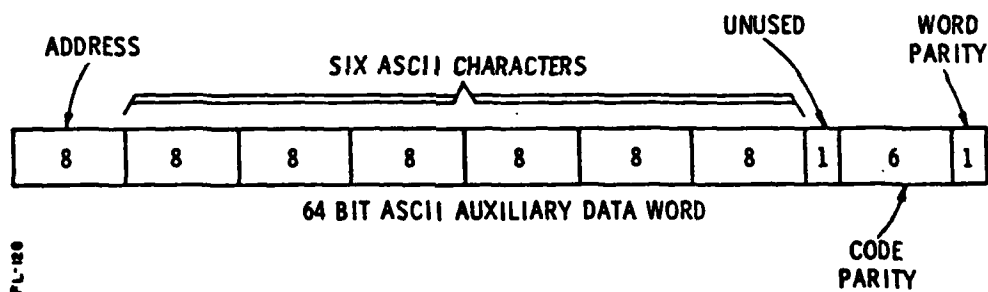
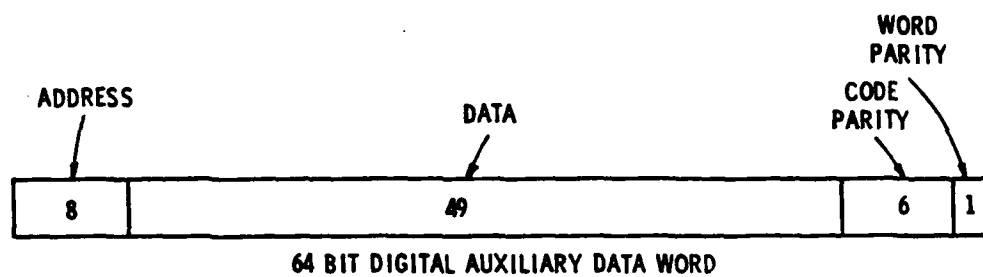


FIGURE 2-16. AUXILIARY DATA FORMAT

monitor detects all angle errors caused by fixed changes in the antenna. These types of errors tend to be common to all angles in the coverage. Sources of these errors might be ice on the radome, antenna settlement, beam scan rate, groups of component failures, aperture blockage, etc. The internal executive monitors detect all time-varying faults (faults that might cause angular error to be angle dependent) and insure system integrity throughout the coverage volume.

In addition to the executive monitors, maintenance monitors continuously monitor site subsystem performance and provide maintenance alerts. Maintenance monitors are designed to anticipate performance failures that will cause the site performance to exceed the limits specified. In general, they monitor component and LRU performance, as opposed to final system performance, and provide maintenance alerts when marginal performance is reached. Except for catastrophic failures, the maintenance monitor, in conjunction with good maintenance and corrective action procedures, minimizes unanticipated system shutdowns. An additional function of the maintenance monitor output is to aid in fault detection

As shown in the simplified block diagram of Figure 2-17, three types of monitor inputs are received by the monitor subsystem: analog, digital, and discrete. Analog monitor inputs are dc voltage samples, for example, a +5 V dc power supply voltage. Digital monitor inputs are signals using a digital format to describe the monitor input such as a sample of the preamble transmitted by the ground subsystem. Discrete monitor inputs indicate a GO/NO-GO decision result which would be the output of a monitor point such as the antenna scan modulator. In this case, the discrete monitor input would be a summary signal indication developed within the antenna enclosure indicating GO or NO-GO performance. Regardless of the type of input signal, monitor inputs are compared against a suitable limit to determine if the monitor point inputs are within the preset limits. Each monitor point input is compared on a real-time basis each time they occur in the signal format. Therefore, azimuth monitor inputs are sampled thirteen times per second, and elevation monitor inputs are sampled forty times per second.

To prevent one-time spurious events from shutting down the ground antenna subsystem or from lighting a maintenance indicator, each comparator output is integrated in a digital integrator. Then, until a specific ratio of bad-to-good events is registered, the latch circuits prevent erratic operation of front panel indicators and site status outputs.

The monitor subsystem timing is developed independently of other system timing and is slaved to the common site 10-MHz



master oscillator and to the sync pulse occurring at the frame rate of 1.69 Hz (592 ms period). The sync pulse is developed within the Local Control/Status assembly.

2.3.5.2 Executive Monitors - Executive monitors check critical system parameters and initiate executive action (automatic site shutdown) when the parameter does not meet a predetermined tolerance. The Bendix concept of executive monitoring employs a local field monitor as the primary executive monitor that provides an end-to-end test of the ground system at critical guidance angles. In addition, key internal executive monitors insure the integrity of all critical system parameters.

Table 2-17 lists the parameters checked by the executive monitors of the AZ and EL subsystems. The AZ and EL systems are independent of one another, with the exception that if the AZ subsystem shuts down, the EL subsystem will also, since sync timing is derived from the AZ system.

2.3.5.3 Maintenance Monitors - The purpose of maintenance monitors is to sense system degradation and raise a maintenance alert prior to an executive shutdown. The maintenance monitor thresholds are generally set higher in order to allow them to achieve this function. Another very important function of the maintenance monitor (in conjunction with the executive monitor) is to locate the fault to the LRU level.

In general, maintenance monitors measure performance at the component level (as opposed to subsystem and system level for the executive monitors) and, in general, parameters measured do not directly cause an executive fault. There are exceptions, of course. For example, TWTA and exciter power output are critical to system performance. However, the executive ERP monitors measure the radiated power. Therefore, the maintenance monitors at the TWTA and exciter level are somewhat redundant to the ERP monitors and are used to flag a decaying output power condition and locate the faulty LRU. Appropriately, the alarm limit for these two monitors is -2.0 dB compared to -3.0 dB on the ERP monitors.

Table 2-18 lists the parameters checked by the maintenance monitors of the AZ and EL subsystems.

2.3.6 Signal Interconnections

All data and signal interfaces between the BN equipments are done via buried cables. Figure 2-18 identifies the major equipments and their interfaces. The cable designations are defined in Table 2-19, which identifies the uses for each cable. The Remote Control/Status unit is located in the AZ equipment

TABLE 2-17. EXECUTIVE MONITORING FOR
BASIC NARROW

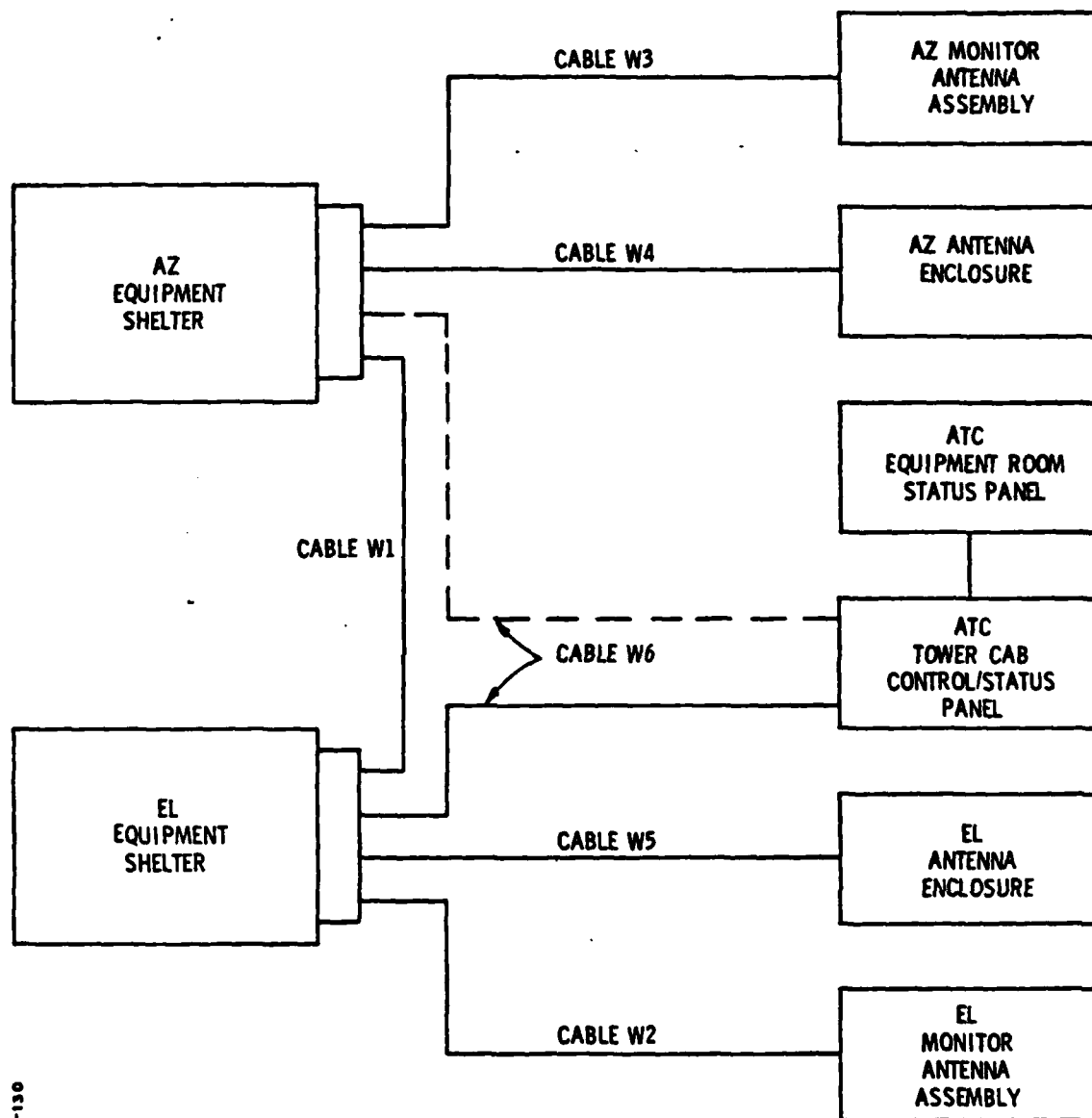
PARAMETER	AZ	EL	SIGNAL	DESCRIPTION	LIMITS
Beam Accuracy	X	X	Digital	Scanned beam angle accuracy	$\pm 0.13^\circ$ AZ $\pm 0.071^\circ$ EL
Test Pulses	X	-	Digital	Time between pulses	± 1 μ sec
Beam ERP	X	X	Analog	Scan beam amplitude	-3 dB
Ident ERP	X	X	Analog	Ident signal amplitude	-3 dB
Upper SLS ERP	-	X	Analog	SLS signal amplitude	-3 dB
Left Rear SLS ERP	X	-	Analog	SLS signal amplitude	-3 dB
Right Rear SLS ERP	X	-	Analog	SLS signal amplitude	-3 dB
Preamble	X	X	Discrete	SLS signal amplitude	-
System Timing	-	X	Digital	Compare sync timing	± 100 μ sec
Site Frequency	X	X	Digital	Measure transmitted frequency	± 10 kHz
Antenna Scan Switch	X	X	Discrete	Check switch operation	-
Scan Modulator	X	X	Discrete	Check modulator operation	-
Scan Control	X	X	Discrete	Check scan control	-
DME Reply Delay	X	-	Discrete	Check reply delay	-
Monitor Timing	X	X	Discrete	Check monitor timing circuit	-
Local Control Panel	X	X	Discrete	Check local control panel	-

TABLE 2-18. MAINTENANCE MONITORING FOR BASIC NARROW

NO.		AZ	EL	SIGNAL (a)	DESCRIPTION	LIMITS
1	BDW #1	X	-	D	Check of basic data word #1	-
2	BDW #2	-	X	D	Check of basic data word #2	-
3	Aux Data	X	-	D	Check of Auxiliary data	-
4	TWTA Output	X	X	A	TWTA power output	-2 dB
5	Exciter Output	X	X	A	Exciter amplitude	-2 dB
6	Data Input	X	-	D	Check of input data	-
7	Sync Presence	-	X	D	Check of sync signal presence	-
8	Phase Modulator	X	X	D	Check of phase modulator	-
9	Amplitude Modulator	X	X	D	Check of amplitude modulator	-
10	UPS - AC Power (b)	X	X	D	AC power, on/off	-
11	UPS - Battery (b)	X	X	D	Battery charge low	-
12	UPS - Reverse (b) Transfer Switch	X	X	D	Transfer switch activated	-
13	Electronics Temp.	X	X	A	Temperature in electronics cabinet	-10C +50C
14	Antenna Temp.	X	X	A	Temperature in antenna enclosure	-10C +50C
15	Data Link	X	X	D	Operation of data link	-
16	Antenna +5 V	X	X	A	Output of +5 V supply	4.510 to 4.985 V
17	Antenna -40 V	X	X	A	Output of -40 V supply	-42.63 to -33.16 V
18	Antenna +24 V	X	X	A	Output of +24 V supply	18.95 to 26.53 V
19	Electronics +5 V	X	X	A	Output of +5 V supply	4.75 to 5.25 V
20	Electronics +15 V	X	X	A	Output of +15 V supply	14.25 to 15.75 V
21	Electronics -15 V	X	X	A	Output of -15 V supply	-15.75 to -14.25 V
22	Electronics +20 V	X	X	A	Output of +20 V supply	19.0 to 21.0 V
23	Monitor +5 V	X	X	A	Output of +5 V supply	4.75 to 5.25 V
24	Monitor +5 V	X	X	A	Output of +5 V supply	4.75 to 5.25 V
25	Monitor +15 V	X	X	A	Output of +15 V supply	14.7 to 15.3 V
26	Monitor -15 V	X	X	A	Output of -15 V supply	-15.3 to -14.7 V

(a) D - discrete
A - analog

(b) Uninterrupted Power Supply is not included in BN system.



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FIGURE 2-18. BASIC NARROW SIGNAL INTERFACE

TABLE 2-19. BN INTERFACE CABLING IDENTIFICATION

CABLE NO.	TYPE	USE
1	6 twpr. #19	1 system sync 2 time reference 3 data link 4,5 intercom 6 spare
2	6 twpr, #19 3/8" coax	1 scanning beam ERP 2 +15 VDC 3 -15 VDC 4-6 spares coax monitor horn output
3	6 twpr, #19 3/8" coax	1 scanning beam ERP 2 +15 VDC 3 -15 VDC 4-6 spares coax monitor horn output
4	18 twpr, #19	1 scan gate 2 pause gate 3 antenna selector switch monitor 4 scan control monitor 5 scan modulator monitor 6 antenna temperature sense 7 antenna +5 V sense 8 antenna +24 V sense 9 antenna -40 V sense 10,11 -40 VDC 12 scan monitor gate 13-18 spares
5	18 twpr, #19	1 scan gate 2 pause gate 3 antenna select #1 4 antenna select #2 5 antenna selector switch monitor 6 scan control monitor 7 scan modulator monitor 8 antenna temperature sense 9 antenna +5 V sense 10 antenna +24 V sense 11 antenna -40 V sense 12 scan monitor gate 13 +15 VDC 14 -15 VDC 15 forward ident ERP 16 upper SLS ERP 17,18 spares
6	3 twpr, #19	1 data link 2,3 intercom

shelter, although its intended purpose is to be located in the ATC cab. When this is done, the Remote Control/Status unit may obtain data from either the AZ or EL equipment shelter, as indicated by the dotted line in the figure.

Figure 2-19 is a block diagram of the data link system in the Basic Narrow equipments. The primary link is between the AZ and EL equipment shelters and the Remote Control/Status. The remote location addresses a particular site (AZ or EL) and then transfers command information. The addressed site immediately responds with status information. If there is no response, a malfunction indication is displayed at the remote location.

Figure 2-20A illustrates the synchronization between the AZ and EL equipment shelters. The EL Site is slaved to the system sync developed within the AZ Site. A time reference (test) signal is also sent to the EL Maintenance Monitor. A second time reference signal is generated by the EL Local Control/Status Unit and fed to the EL Maintenance Monitor where it is compared to the test signal from the AZ Site. A time difference greater than 100 μ s between the two signals, or loss of either signal, initiates an EL Site shutdown.

For the temporary installations during the worldwide demonstrations at operational airports (see Section 5.4), it was not feasible or economical to install the W1 cable between the AZ and EL shelters. In order to maintain sync between these equipments, the test pulses radiated by the AZ subsystem were used to generate the EL sync signal as shown in Figure 20B. The TO and FRO test pulses (Figure 2-14) are picked up by a microwave horn antenna mounted atop the EL equipment shelter. The pulses are detected and processed to drive a waveform generator which outputs a pulse every 592 msec. This pulse is inputted to the EL Local Control/Status equipment in the same manner as the sync signal received via the buried cable. Using this temporary sync system, it is not possible to transmit time reference or data signals.

2.4 SMALL COMMUNITY GROUND SUBSYSTEM

2.4.1 General

The Small Community (SC) ground subsystem is composed of two functional elements:

- approach azimuth element (AZ)
- approach elevation element (EL)

These elements are physically contained in two major equipment groups, the AZ equipment group, and the EL equipment group. Each equipment group consists of a field monitor horn and a shelter which houses the antennas and electronics. A high level system block diagram is shown in Figure 2-21.

The SC system was deployed at time of testing on Runway 8/26 at NAFEC (see Figure 2-6). The placement of the AZ and EL equipments relative to the runway is shown in Figure 2-22.

An artist's rendition of the AZ equipment, Figure 2-23, shows the location of the various antennas. The major components in the AZ equipment are listed in Table 2-20 and shown in Figure 2-21.

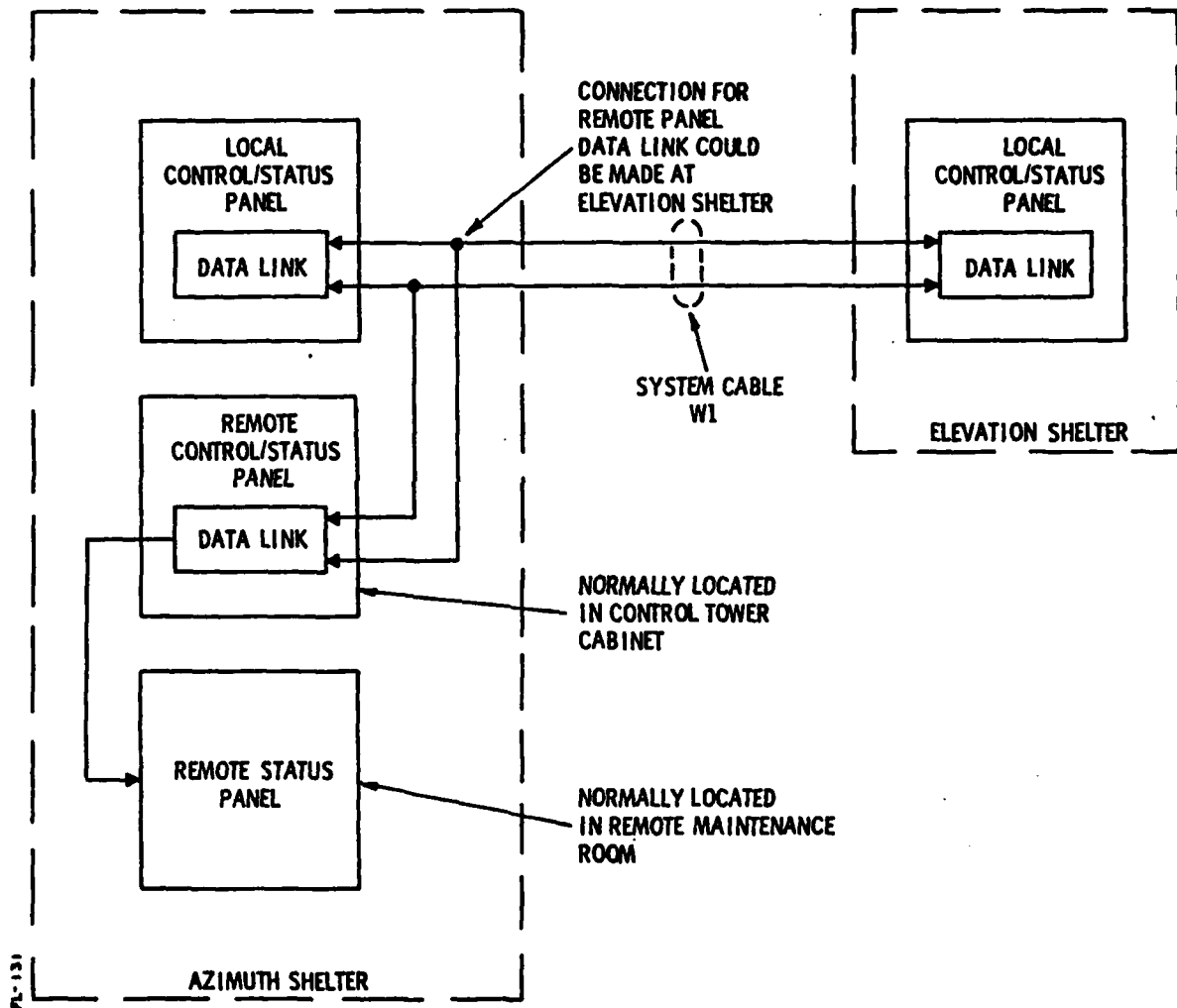
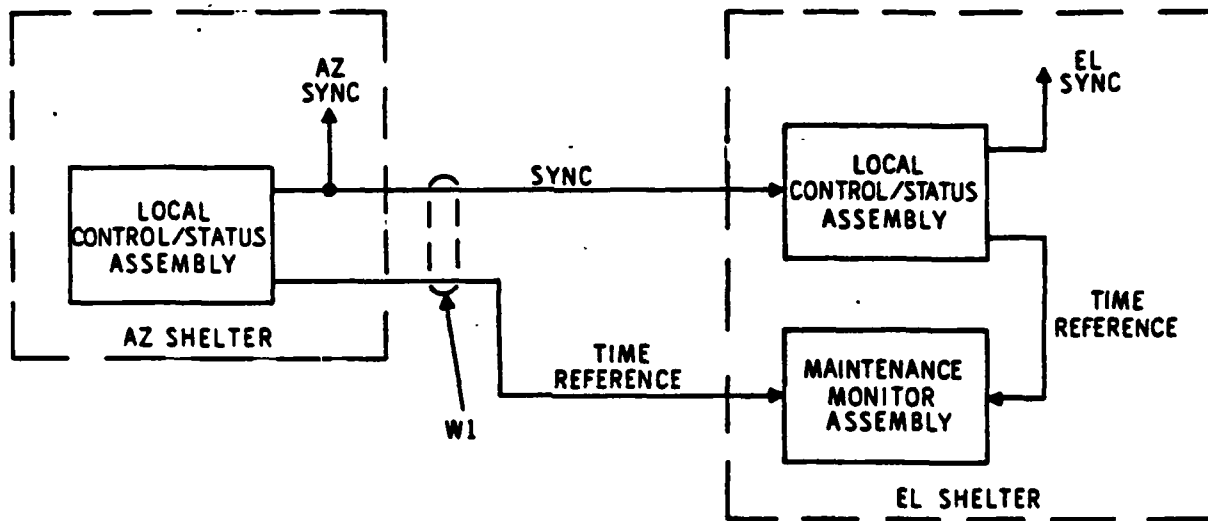
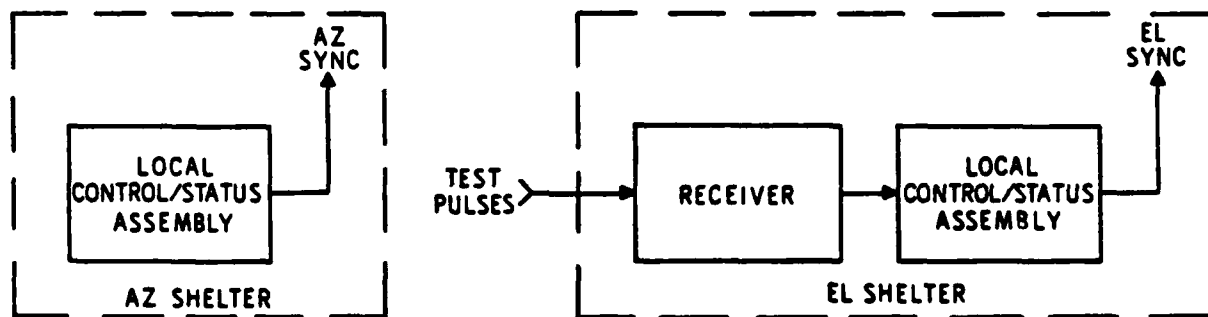


FIGURE 2-19. DATA LINK SYSTEM



A.-USING BURIED CABLE



B.-USING AIR SYNC

MLS-RPT-210A

FIGURE 2-20. BASIC NARROW SYNC SYSTEM

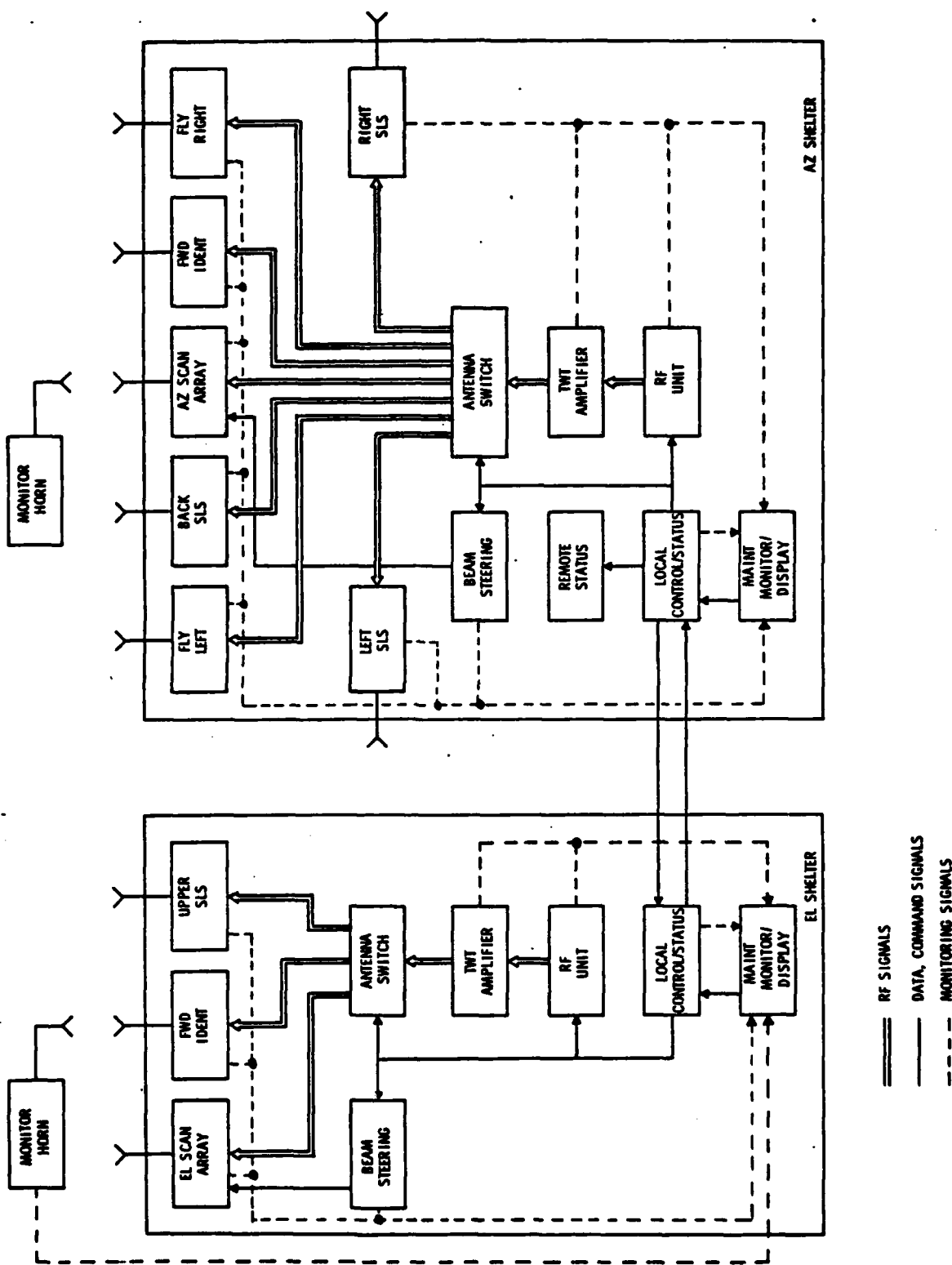


FIGURE 2-21. SC GROUND SUBSYSTEM BLOCK DIAGRAM

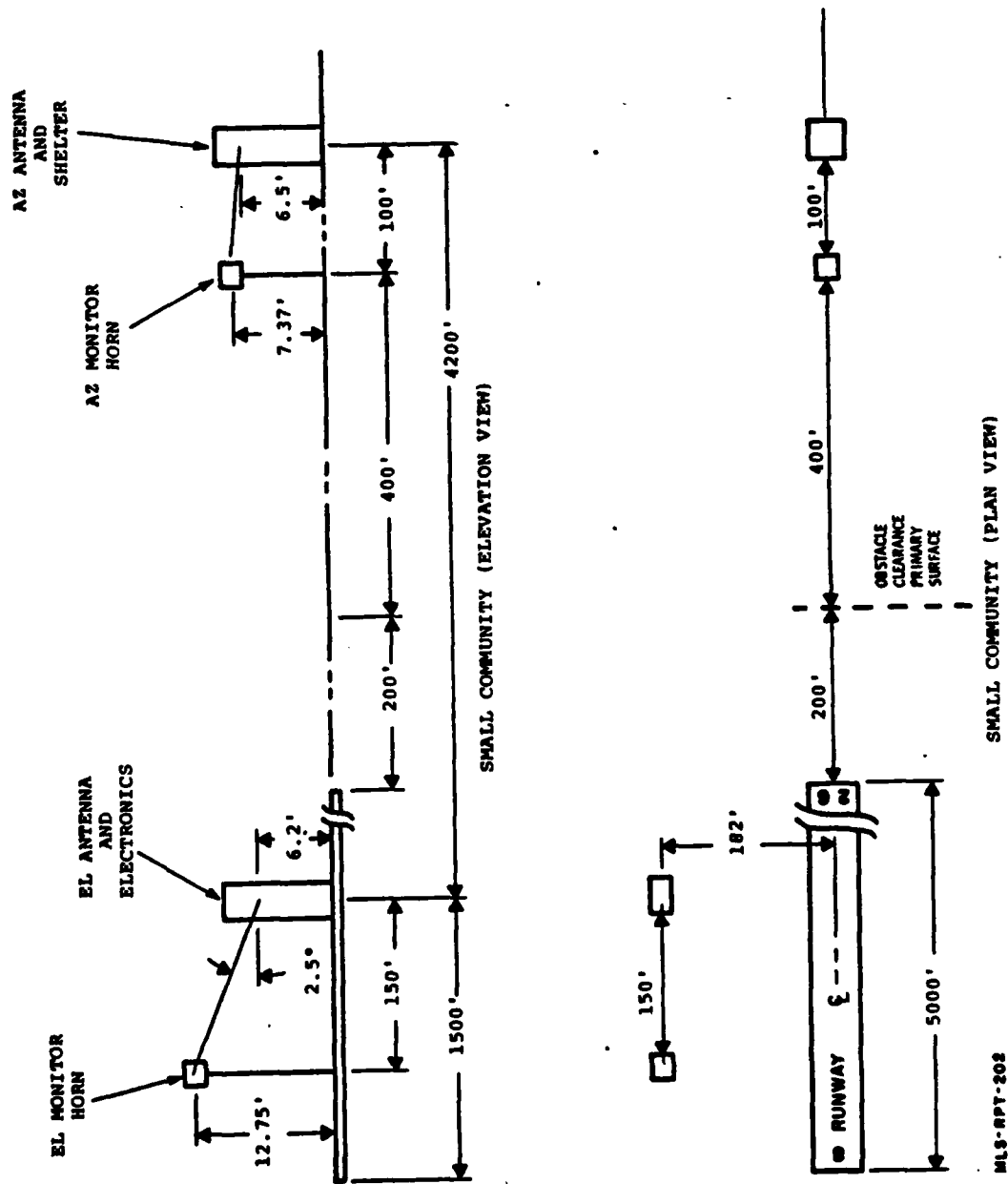


FIGURE 2-22. SMALL COMMUNITY GROUND EQUIPMENT CONFIGURATION ON RUNWAY 8/26

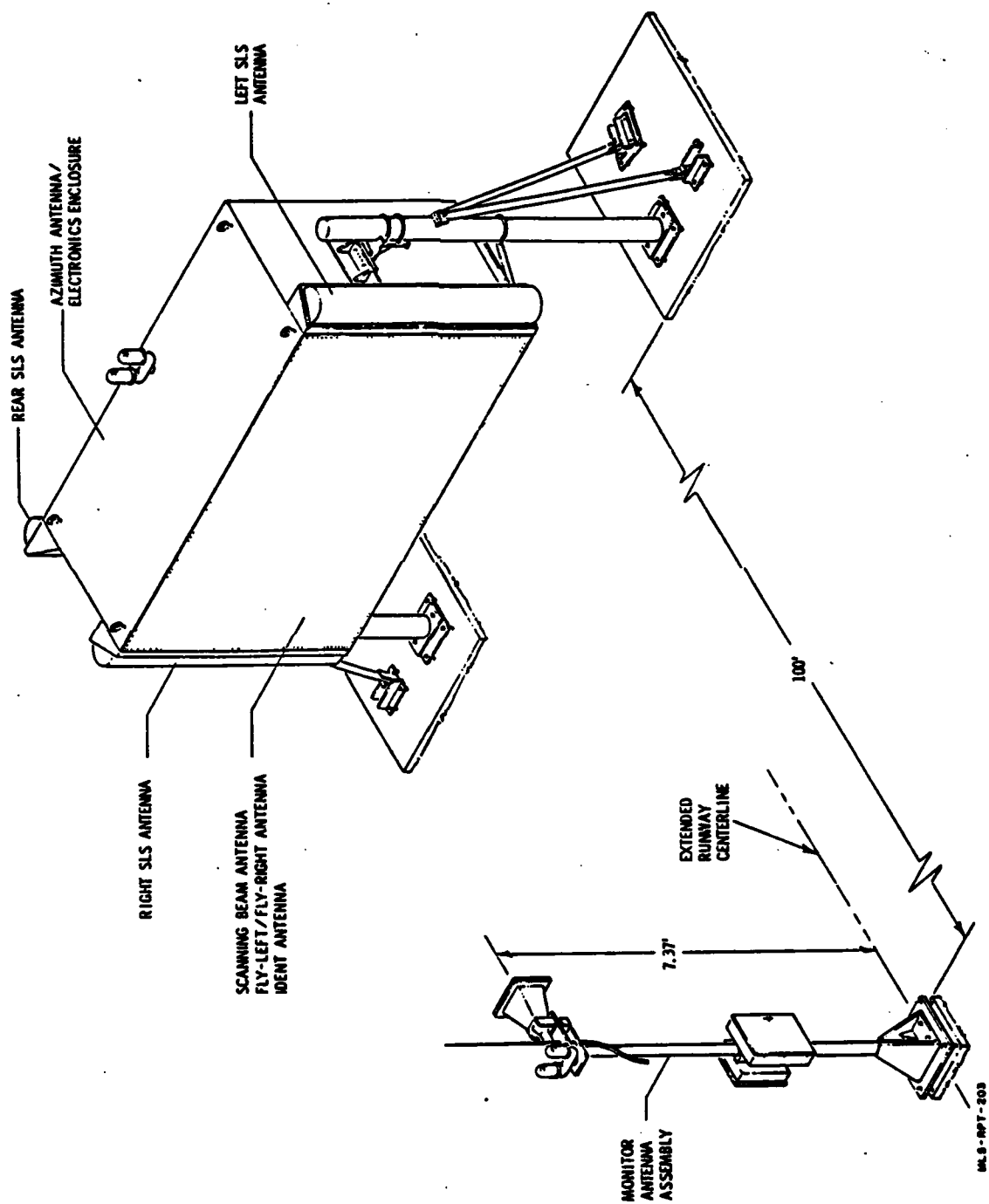


FIGURE 2-23. SMALL COMMUNITY AZIMUTH EQUIPMENT

TABLE 2-20. MAJOR COMPONENTS OF SMALL COMMUNITY
AZ SUBSYSTEM

TWT amplifier
RF unit
Local control/status
Maintenance monitor
Antenna select switch
Forward Ident antenna
Left/Right clearance beam antenna
Left SLS antenna
Right SLS antenna
Rear SLS antenna
Scanning beam array
Beam steering
Remote status

Figure 2-24 is a composite of the azimuthal coverage from the AZ site. Included are the scanning beam coverage and patterns of the forward ident, the left and right sidelobe suppression, left and right clearance beams, and the rear sidelobe suppression antennas. These patterns are described in detail in paragraph 3.2.1.

A sketch of the EL equipment is shown in Figure 2-25. The major components in the EL equipment are listed in Table 2-21 and shown in Figure 2-21.

TABLE 2-21. MAJOR COMPONENTS OF SMALL COMMUNITY
EL SUBSYSTEM

TWT amplifier
RF unit
Local control/status
Maintenance monitor
Antenna select switch
Forward IDENT antenna
Upper SLS antenna
Scanning beam array
Beam steering

Figure 2-26 is a composite of the vertical coverage from the EL site. Included are the scanning beam coverage and patterns of the forward ident and upper sidelobe suppression. These patterns are described in detail in paragraph 3.2.2.

The prime power requirements for the SC ground subsystem are listed in Table 2-22.

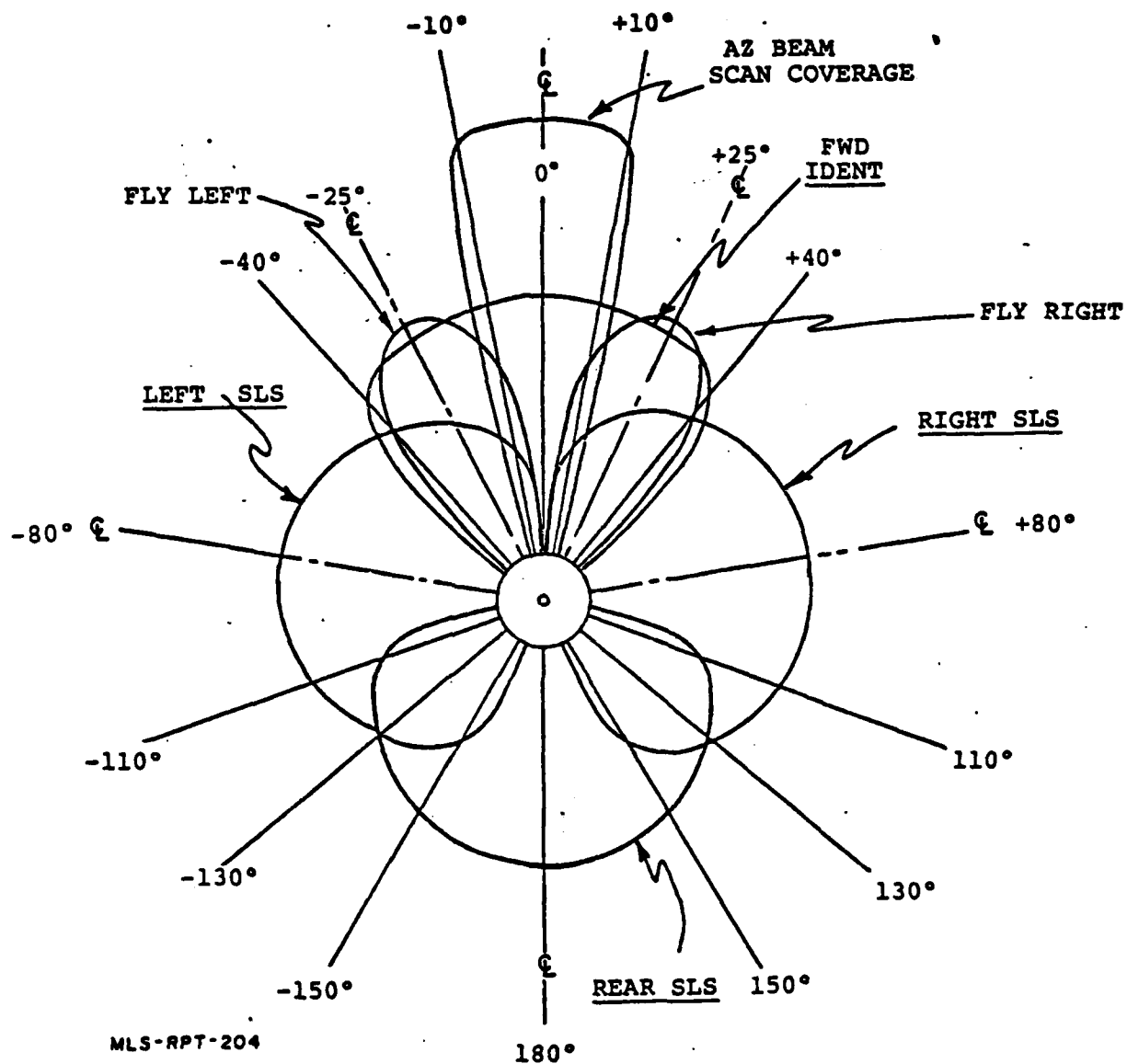


FIGURE 2-24. AZIMUTH COVERAGE, SMALL COMMUNITY
AZ SUBSYSTEM

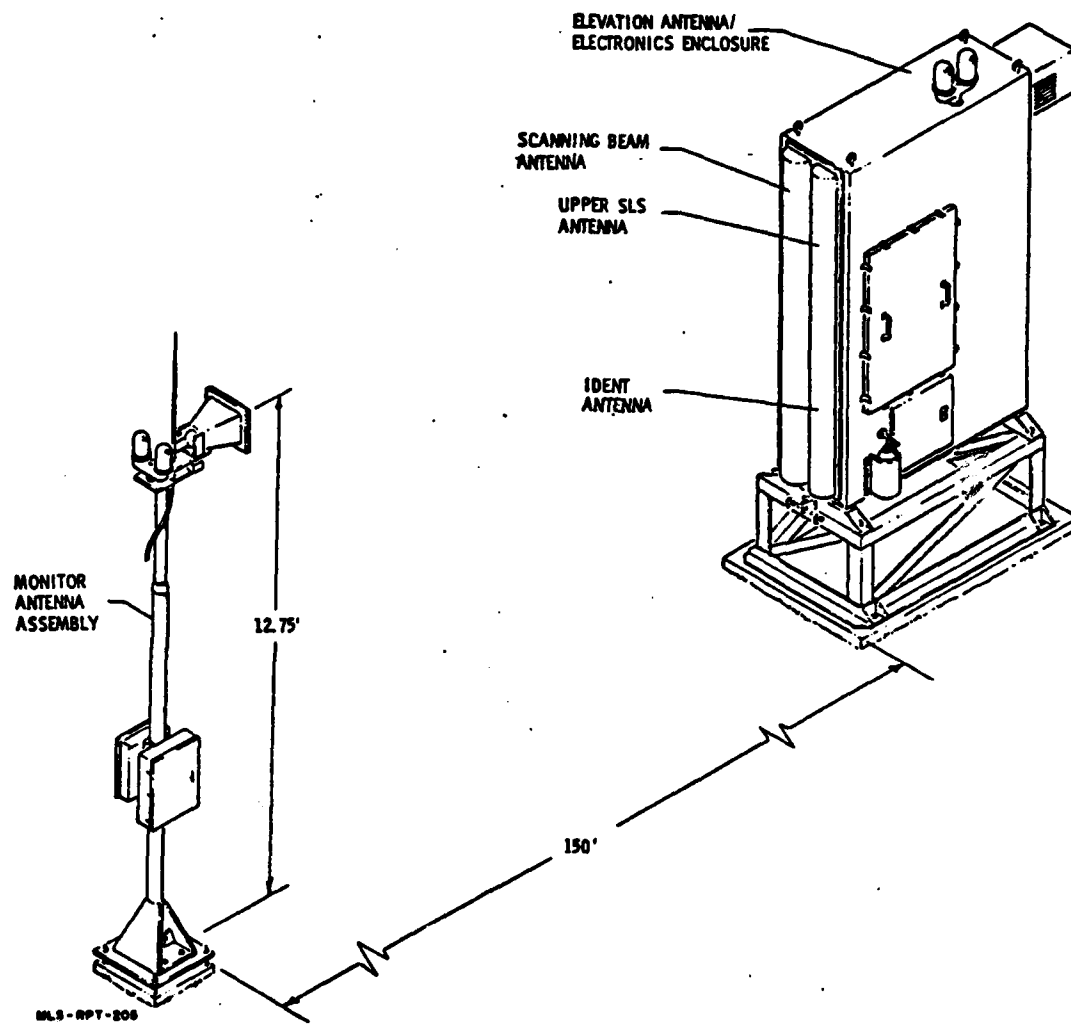
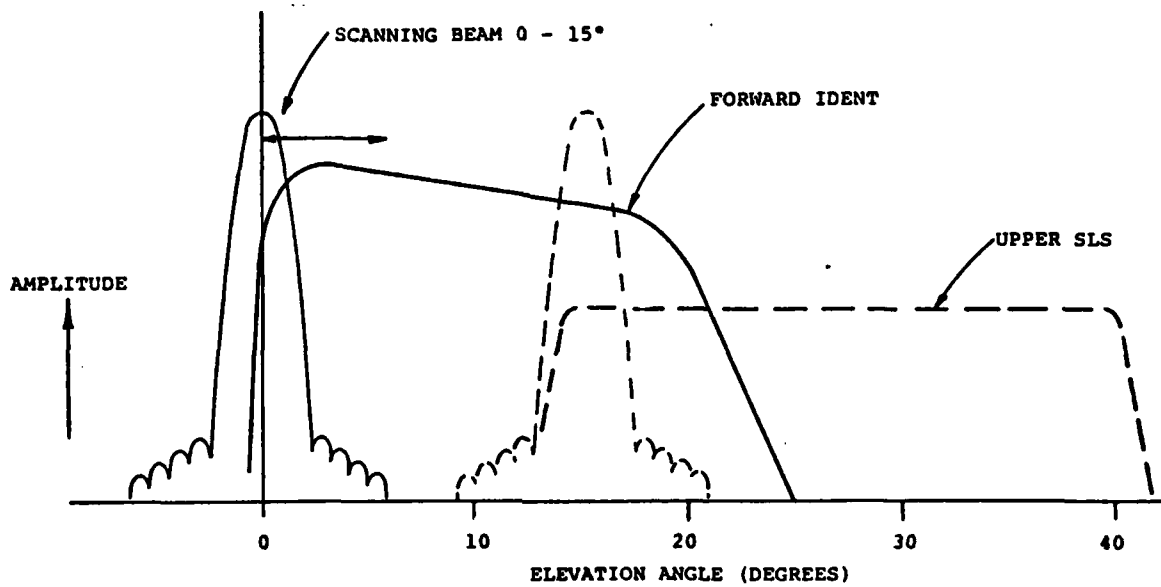


FIGURE 2-25. SMALL COMMUNITY ELEVATION EQUIPMENT



MLS-RPT-206

FIGURE 2-26. ELEVATION COVERAGE, SMALL COMMUNITY EL SUBSYSTEM

TABLE 2-22. SC PRIME POWER REQUIREMENTS (VA)

Function	AZ @ 120 V	EL @ 120 V	Total @ 120 V
Electronics	834 VA (a)	502.7 VA	1,336.7 VA
Environmental	3,036 VA	2,717.2 VA	5,753.2 VA
Deicing	7,627.2 VA	970.8 VA	8,598 VA
Lighting (b)	2,880 VA	3,016.4 VA	5,896.4 VA
	14,377.2 VA	7,207.1 VA	21,584.3 VA

(a) Includes 34 watts for Remote Status Panel

(b) Assumes utility outlets fully loaded

2.4.2 System Performance

This section describes the system features and performance of the SC ground subsystem. Included are the subsystem error budget, accuracy goals, and antenna scan angles, beamwidths and gains. A more complete description of the antenna patterns is given in paragraph 3.2, and measured performance data is presented in Section 5.

2.4.2.1 Accuracy Goals and Error Budget - Although the SC system must meet the accuracy specifications defined in paragraph 2.2.2, the partitioning of the accuracy requirements among the ground subsystem and the airborne equipment is done in such a manner that individual subsystem specifications are achievable, while meeting the overall system requirements.

Table 2-23 shows the partitioning of the Small Community system accuracy requirements among the ground subsystem, the airborne equipment, and multipath effects, broken down to the azimuth and elevation functional elements. The ground subsystem and airborne equipment accuracies are taken from FAA-ER-700-04; the multipath effects were estimated by assigning to the multipath allotment that error which would cause the RSS of the ground, airborne, and multipath errors to add up to the system error.

The errors assigned to the ground and multipath sources provide the basis for defining the ground subsystem design specifications and budgeting system tolerances. These are discussed in the next section.

2.4.2.2 System Design Parameters - Since MLS is an air-derived system, performance is dictated almost entirely by the characteristics of the scanning beam and the airborne receiver. Although the actual multipath environment cannot be controlled through system design, the multipath effects can be minimized by judiciously specifying the radiated patterns and applying known circuit techniques in the receiver. Considering only the ground system at this point, the scanning beam characteristics are determined completely by the antenna with its associated beam steering. Table 2-24 lists the Small Community azimuth and elevation antenna specifications. The specifications marked with an asterisk are defined in the FAA-ER-700 series of specifications. The remaining specifications are based on and are consistent with the requirements listed in Table 2-23.

TABLE 2-23. ALLOCATION OF SMALL COMMUNITY
SYSTEM ERRORS (2σ)

AZIMUTH ELEMENT

ERROR SOURCE	BIAS (DEG)	PFN (DEG)	CMN (DEG)	PFE (DEG)
GROUND	0.200	0.100	0.024	0.210
AIRBORNE	0.050	0.091	0.050	0.051
MULTIPATH	0.204	0.065	0.083	0.249
SYSTEM	0.290	0.150	0.100	0.330

ELEVATION ELEMENT

ERROR SOURCE	BIAS (DEG)	PFN (DEG)	CMN (DEG)	PFE (DEG)
GROUND	0.075	0.068	0.016	0.076
AIRBORNE	0.050	0.056	0.050	0.051
MULTIPATH	0.059	0.081	0.085	0.134
SYSTEM	0.108	0.120	0.100	0.162

TABLE 2-24. SMALL COMMUNITY
ANTENNA SPECIFICATIONS

PARAMETER	AZ	EL
3 dB beamwidth (boresight)	$3^{\circ} \pm 0.2^{\circ}$	$2^{\circ} \pm 0.1^{\circ}$
15 dB beamwidth (max.)	6.2°	4.1°
*Lateral coverage	$\pm 40^{\circ}$	$\pm 10^{\circ}$
*Vertical coverage	1.0 to 15°	1 to 15°
*Scan guidance coverage	$\pm 10^{\circ}$ (lateral) 1 to 15° (vertical)	$\pm 10^{\circ}$ (lateral) 1.9 to 10.67° (vertical)
Sidelobe level (max.)	-20 dB	-20 dB
Beam step size (max.)	0.3°	0.2°
Switching rate (max.)	1 μ sec/ transition	1 μ sec/ transition
*Scan rate	20,000 deg/sec	20,000 deg/sec
Overscan	1/2 beamwidth	1/2 beamwidth
Gain (min.)	20 dBi	20 dBi
*Polarization	Vertical	Vertical
Underside cutoff (min.)	6 dB/degree at 0° elevation	N/A
TO-FRO scans/sec	13.5	40.5
Lateral gain variation	N/A	-3 dB @ $\pm 20^{\circ}$ -7 dB @ $\pm 40^{\circ}$
Effective radiated radiated power (ERP)	≥ 46 dBm	≥ 46 dBm
ERP (L/R clearance beams)	≥ 42 dBm	-
ERP (Forward Ident)	≥ 42 dBm	≥ 42 dBm
ERP (SLS)	≥ 35 dBm	≥ 33 dBm

*Defined by FAA-ER-700 series documents.

2.4.3 Power Budget

The power budget for the Small Community System is shown in Table 2-25. This table uses the same format as Table 2-16, the power budget for the Basic Narrow system, and all comments and descriptions presented in paragraph 2.3.3 apply here.

As shown in the last two rows of Table 2-25, there is an adequate power margin under worst-case conditions and a substantial margin under RSS conditions.

2.4.4 Signal Format

The signal format for the SC system is very similar to that for the BN system. The SC signal format cycle is shown in Figure 2-12. The detailed azimuth and elevation signal formats are described below.

The SC AZ subsystem differs from the BN AZ subsystem in that proportional guidance is limited to ± 10 degrees in azimuth. Sector guidance (fly left, fly right) is provided out to ± 40 degrees in azimuth. Thus, the SC AZ signal format has two additional time slots to accommodate the fly left/fly right signals, and the time slots for the TO/FRO scanning beam are less. In addition, the SC system has a back sidelobe suppression function. The detailed azimuth signal format is shown in Figure 2-27. All of the functions have the same definitions as those given in paragraph 2.3.4, the BN signal format. The two additional guidance functions (fly left/fly right) are transmitted from clock pulses 25 to 27 and 27 to 29, respectively. The back SLS is transmitted from clock pulse 29 to 31. The TO and FRO scans are centered (0° scan) at clock pulses 83.5 and 185.5. The TO scan is transmitted from clock pulse 74.5 to 83.5, and the FRO scan from clock pulse 176.5 to 185.5.

Basic data word #1 (Figure 2-14) is transmitted from the AZ site during part B of sequences 2, 4, 6, and 8.

The elevation signal format is identical to that of the BN system, Figure 2-13, and the comments that apply to the BN system apply to the SC system also.

The Basic Data Word formats are the same as for the BN system described in paragraph 2.3.4.

TABLE 2-25. POWER BUDGET FOR THE SMALL COMMUNITY
GROUND SUBSYSTEM

	Azimuth			Elevation	
	Array	Preamble	Clearance	Array	Preamble
Transmitter Power	43.0	43.0	43.0	43.0	43.0
Cable Losses	- 0.7	- 0.7	- 0.7	- 1.1	- 1.1
Component Losses	- 2.5	- 2.5	- 2.5	- 2.0	- 2.0
Antenna Gain (b)	23.3	13.8	17.3	20.3	14.7
*AZ Coverage Loss (a)	- 0.1	- 1.5	- 1.0	- 0.9	- 1.5
*EL Coverage Loss (a)	- 3.6	- 3.6	- 3.6	0	- 3.6
Monitor Limit Loss	- 3.0	- 3.0	- 3.0	- 3.0	- 3.0
Propagation Loss (c)	-135.9	-135.9	-135.9	-135.5	-135.5
Atmospheric Loss	- 0.2	- 0.2	- 0.2	- 0.2	- 0.2
*Rain Loss	- 1.7	- 1.7	- 1.7	- 1.7	- 1.7
*Polarization Loss	- 0.5	- 0.5	- 0.5	- 0.5	- 0.5
Min. Power at A/C	-83.9	-94.8	-98.4	-81.6	-93.4
Spec. Power at A/C	-92.0	-96.0	-96.0	-92.0	-96.0
Minimum Margin	8.1	1.2	5.2	10.4	2.6
RSS Margin	10.1	4.4	8.0	11.5	5.8

Power in dBm; gains, losses, and margins in dB

* RSS of these terms gives RSS margin

(a) Worst case coverage loss, $\pm 40^\circ$ clearance, $\pm 10^\circ$ azimuth,
 1° to 15° elevation

(b) Assume 0 dBi gain aircraft antenna

(c) Assume EL distance = 15 nmi, AZ distance = 15.7 nmi



FIGURE 2-27. SMALL COMMUNITY AZ SIGNAL FORMAT

MLS-RPT-207

2.4.5 Monitoring

2.4.5.1 General - The design philosophy and rationale for the Small Community monitoring system is identical to that for the Basic Narrow system described in paragraph 2.3.5.1. Differences exist in the number of components being monitored and in assigning fault level thresholds. The next two sections describe the executive and maintenance monitoring for the Small Community ground subsystem.

2.4.5.2 Executive Monitors - Executive monitors check critical system parameters and initiate executive action (automatic site shutdown) when the parameter does not meet a predetermined tolerance. The Bendix concept of executive monitoring employs a local field monitor as the primary executive monitor that provides an end-to-end test of the ground system at critical guidance angles. In addition, key internal executive monitors insure the integrity of all critical system parameters.

Table 2-26 lists the parameters checked by the executive monitors of the AZ and EL subsystems. The AZ and EL systems are independent of one another, with the exception that, if the AZ subsystem shuts down, the EL subsystem will also since sync timing is derived from the AZ system.

2.4.5.3 Maintenance Monitors - The purpose of maintenance monitors is to sense system degradation and raise a maintenance alert prior to an executive shutdown. The maintenance monitor thresholds are generally set lower in order to allow them to achieve this function. Another very important function of the maintenance monitor (in conjunction with the executive monitor) is to locate the fault to the LRU level.

In general, maintenance monitors measure performance at the component level (as opposed to subsystem and system level for the executive monitors) and, in general, parameters measured do not directly cause an executive fault. There are exceptions, of course. For example, TWTA and exciter power output are critical to system performance. However, the executive ERP monitors measure the radiated power. Therefore, the maintenance monitors at the TWTA and exciter level are somewhat redundant to the ERP monitors and are used to flag a decaying output power condition and locate the faulty LRU. Appropriately, the alarm limit for these two monitors is -2.0 dB compared to -3.0 dB on the ERP monitors.

Table 2-27 lists the parameters checked by the maintenance monitors of the AZ and EL subsystems.

TABLE 2-26. EXECUTIVE MONITORING FOR SMALL COMMUNITY

No. PARAMETER	AZ	EL	SIGNAL	DESCRIPTION	LIMITS
1 Beam Accuracy	X	X	Digital	Scanned beam angle accuracy	+0.20° AZ +0.075° EL
2 Test Pulses	X	-	Digital	Time between pulses	+1 μ sec
3 Beam ERP	X	X	Analog	Scan beam amplitude	-3 dB
4 Ident ERP	X	X	Analog	Ident signal	-3 dB
5 Fly Left ERP	X	-	Analog	Fly Left Signal amplitude	-3 dB
6 Fly Right ERP	X	-	Analog	Fly Right Signal amplitude	-3 dB
7 Upper SLS ERP	-	X	Analog	SLS signal amplitude	-3 dB
8 Left SLS ERP	X	-	Analog	SLS signal amplitude	-3 dB
9 Right SLS ERP	X	-	Analog	SLS signal amplitude	-3 dB
10 Rear SLS ERP	X	-	Analog	SLS signal amplitude	-3 dB
11 Preamble	X	X	Discrete	Status	-
12 System Timing	-	X	Digital	Compare sync timing	+100 μ sec
13 Site Frequency	X	X	Digital	Measure transmitted freq.	+10 kHz
14 Antenna Scan Switches	X	X	Discrete	Check switch operation	-
15 Scan Modulator	X	X	Discrete	Check modulator operation	-
16 Scan Control	X	X	Discrete	Check scan control	-
17 Monitor Timing	X	X	Discrete	Check monitor timing circuit	-
18 Local Control Panel	X	X	Discrete	Check local control panel	-

TABLE 2-27. MAINTENANCE MONITORING FOR SMALL COMMUNITY

NO.		AS	EL	SIGNAL(a)	DESCRIPTION	LIMITS
1	BDW #1	X	-	D	Check of basic data word #1	-
2	BDW #2	-	X	D	Check of basic data word #2	-
3	TWTA Output	X	X	A	TWTA power output	-2 dB
4	Exciter Output	X	X	A	Exciter amplitude	-2 dB
5	Sync Presence	-	X	D	Check of sync signal presence	-
6	Phase Modulator	X	X	D	Check of phase modulator	-
7	Amplitude Modulator	X	X	D	Check of amplitude modulator	-
8	UPS - AC Power(b)	X	X	D	AC power, on/off	-
9	UPS - Battery(b)	X	X	D	Battery charge low	-
10	UPS - Reverse(b) Transfer Switch	X	X	D	Transfer switch activated	-
11	Electronics Temp.	X	X	A	Temperature in antenna/electronics enclosure	-10C +50C
12	Antenna Temp.	X	X	A	Temperature in antenna/electronics enclosure	-10C +50C
13	Data Link	X	X	D	Operation of data link	-
14	Antenna +5 V	X	X	A	Output of +5 V antenna/electronics supply	4.75 to 5.25 V
15	Antenna -40 V	X	X	A	Output of -40 V supply	-42.63 to -33.16 V
16	Antenna +24 V	X	X	A	Output of +24 V supply	18.95 to 26.53 V
17	Electronics +5 V	X	X	A	Output of +5 V antenna/electronics supply	4.75 to 5.25 V
18	Electronics +15 V	X	X	A	Output of +15 V supply	14.25 to 15.75 V
19	Electronics -15 V	X	X	A	Output of -15 V supply	-15.75 to -14.25 V
20	Electronics +20 V	X	X	A	Output of +20 V supply	19.0 to 21.0 V
21	Monitor +5 V	X	X	A	Output of +5 V supply	4.75 to 5.25 V
22	Monitor +5 V	X	X	A	Output of +5 V supply	4.75 to 5.25 V
23	Monitor +15 V	X	X	A	Output of +15 V supply	14.7 to 15.3 V
24	Monitor -15 V	X	X	A	Output of -15 V supply	-15.3 to -14.7 V

(a) D - discrete
A - analog

(b) Uninterrupted Power Supply is not included in SC system.

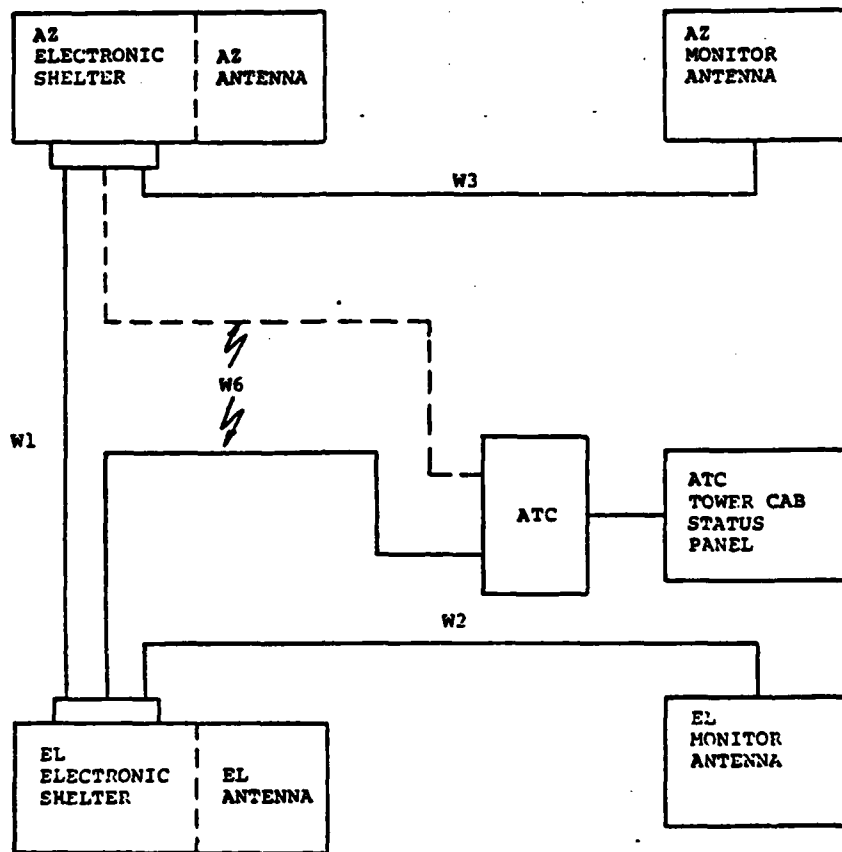
2.4.6 Signal Interconnections

All data and signal interfaces between the SC equipments is done via buried wires and cables. Figure 2-28 identifies the major equipments and their interfaces. The numbers refer to the cable designations in Table 2-28, which identify the uses for each cable. The Remote Status unit is located in the AZ equipment shelter, although its intended purpose is to be located in the ATC cab. When this is done, the Remote Status unit may obtain data from either the AZ or EL equipment shelter, as indicated by the dotted line in the figure.

TABLE 2-28. SC INTERFACE CABLING IDENTIFICATION

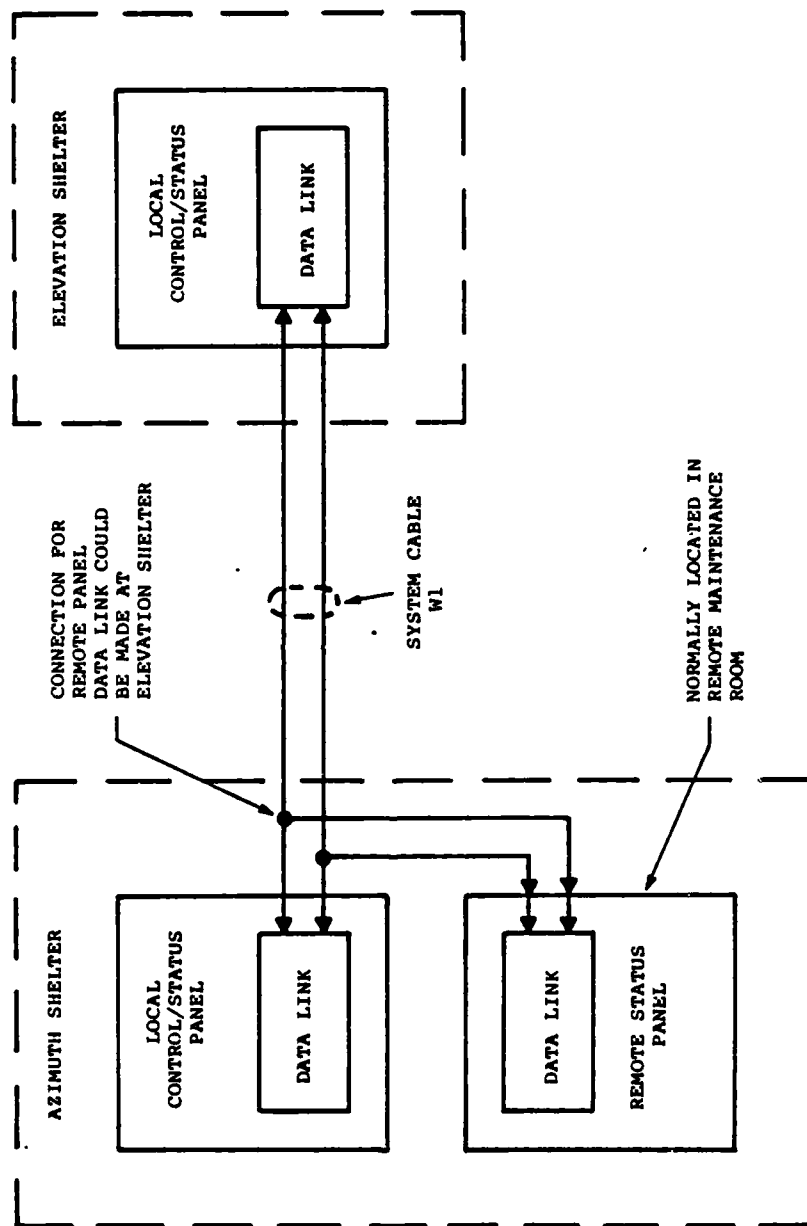
CABLE NO.	TYPE	USE
1	6 twpr, #19	1. system sync 2. time reference 3. data link 4. } intercom 5. } 6. spare
2 & 3	6 twpr, #19 3/8" coax	1. scanning beam ERP 2. +15 VDC 3. -15 VDC 4. } 5. } spares 6. } coax monitor horn signal
6	6 twpr, #19	1. data link 2. } intercom 3. } 4. } 5. } spares 6. }

Figure 2-29 is a block diagram of the data link system in the Small Community equipments. The primary link is between the AZ and EL sites and the Remote Status. The remote location addresses a particular site (AZ or EL) and then transfers command information. The addressed site immediately responds with status information. If there is no response, a malfunction indication is displayed at the remote location.



MLS-RPT-208

FIGURE 2-28. SMALL COMMUNITY SIGNAL INTERFACE CABLES



MLS-RPT-209

FIGURE 2-29. SMALL COMMUNITY DATA LINK SYSTEM

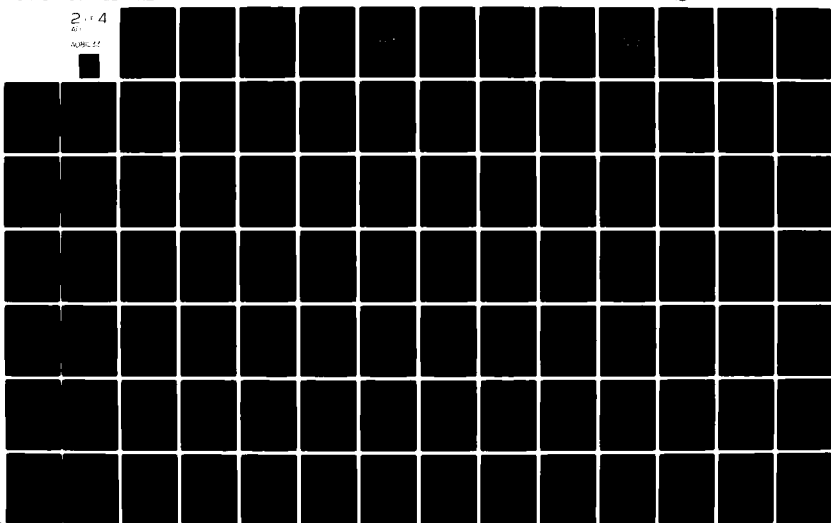
AD-A081 233

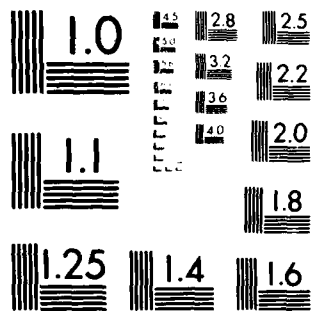
BENDIX CORP BALTIMORE MD COMMUNICATIONS DIV F/0 17/7
MICROWAVE LANDING SYSTEM (MLS). PHASE III. (BASIC NARROW & SHAL--ETC(U)
JUN 78 DOT-FA72WA-2801
MLS-BCD-R-2801-1-VOL-1 NL

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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Figure 2-30A illustrates the synchronization connections between the AZ and EL equipment shelters. The EL site is slaved to the system timing sync from the AZ site. A time reference (test) signal is also sent to the EL maintenance monitor. A time reference signal is also generated by the EL local control/status unit and fed to the EL maintenance monitor where it is compared to the test signal from the AZ site. A time difference greater than 100 μ sec between the two signals initiates an EL site shutdown.

An air-derived sync system, Figure 2-30B, was also used in the Small Community demonstrations. Operation is identical to that described for the Basic Narrow system in paragraph 2.3.6.

2.5 AIRBORNE EQUIPMENT

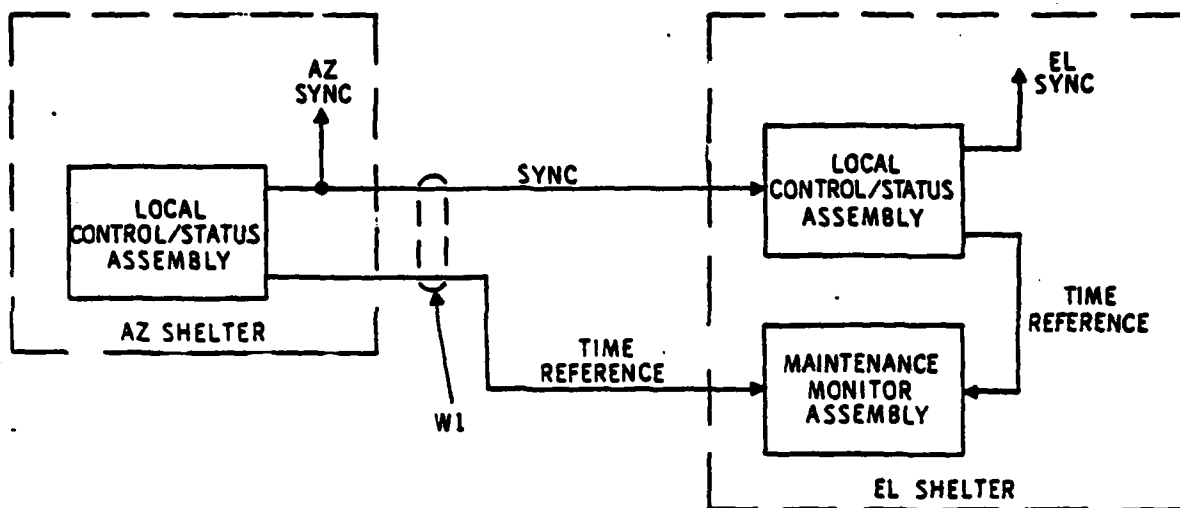
2.5.1 General

The Avionics System program objectives include the design, development, fabrication, documentation, and test and evaluation of prototype models of Small Community and Basic Narrow angle receivers, control panels, auxiliary data display units, antennas, and angle receiver test sets. Initially, the avionics DME subsystem objective was the use of commercial, off-the-shelf, L-band DME interrogators, with 600 ft (2 σ) ranging accuracy. As Phase III evolved, the DME airborne system objectives were upgraded to require feasibility models of DME interrogators and associated data readouts to reflect a MLS system ranging accuracy of 100 ft (2 σ). The MLS avionics equipments were installed on three different aircraft types (Aerocommander, DC-6, and CV-880) and evaluated during field testing.

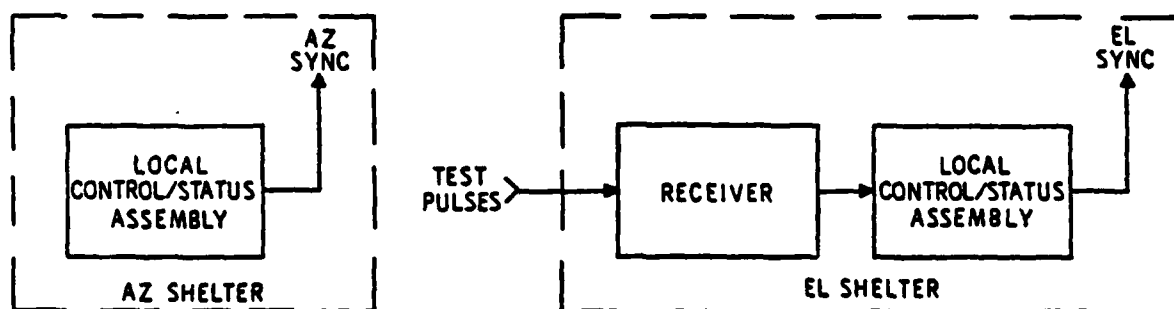
All objectives stated above have been achieved. A major achievement was the size, weight, and power reduction which was made possible by the implementation of extended use of micro-processor, MSI, and LSI circuit designs. This achievement is most instrumental in ensuring low cost, high quality production avionics hardware. Table 2-29 lists the sizes, weights, and power dissipations of the major Basic Narrow avionics system components.

TABLE 2-29. BASIC NARROW AIRBORNE EQUIPMENT SIZE, WEIGHT, AND PRIME POWER

EQUIPMENT	SIZE	WEIGHT (LBS)	POWER (WATTS)
Angle receiver w/mount	3/8 short ATR	11.25	40.0
Control Panel	Standard	1.75	6.0
Aux Data Panel	Standard	1.75	15.0
Antennas (2) w/switch	-	1.55	-
DME w/indicator & mount	1/2 short ATR	13.10	75.0
DME antenna	-	0.40	-
Totals		29.80	136.0



A.-USING BURIED CABLE



B.-USING AIR SYNC

MLS-RPT-210A

FIGURE 2-30. SMALL COMMUNITY SYNC SYSTEM

The following paragraphs are devoted to a general description of the airborne equipment design and installations. A more detailed description of the airborne system components is presented in Section 4 of this report.

2.5.2 Airborne System Functional Description

The MLS system is an air-derived system which utilizes a C-Band Time Reference Scanning Beam (TRSB) technique for the transmission of angle data in conjunction with a synchronized time division multiplex technique for DPSK transmission of timing, control, identification, and status data at the same C-band frequency. Conventional L-Band DME techniques are utilized for ranging data with suitable modification of the first pulse shape and signal processing to achieve improved ranging accuracies. The DME subsystem functions independently of the C-band angle and data system.

Any MLS avionics system configuration can be achieved by the appropriate use of the functions provided in the MLS TRSB signal formats, which also contains provisions for growth. Possible avionics system configurations include:

- Small Community Configurations
- Basic Narrow Configurations
- Basic Wide Configurations
- Expanded Configurations
- Tactical Configurations
- Shipboard Configurations

During Phase III, the Small Community (SC) and Basic Narrow (BN) avionics configurations were designed, fabricated, installed, and tested. In the BN system configuration, the elevation, approach azimuth and range functions are utilized. In the SC system configuration, only the elevation and approach azimuth functions are utilized.

Prior to describing the airborne systems, the functional utility of the MLS TRSB signal formats must be understood.

The signal format (see paragraph 2.3.4) in the "TO" scan and the "FRO" scan portions of the angle function format is an electronically scanned CW signal during the designated time periods. The angle receiver measures elevation angle with respect to zero elevation angle and azimuth angle with respect to runway centerline, using the TO/FRO scan data as follows:

- a. As the TO beam sweeps by the aircraft, a beam envelope is generated in the angle receiver as shown in Figure 2-31.
- b. A dwell gate is developed as the beam exceeds a preestablished threshold which is referenced to the beam peak amplitude.
- c. The time of occurrence of the dwell gate leading and trailing edges are averaged to determine the TO centroid of the dwell gate.
- d. Steps a-c are repeated for the FRO beam. A FRO centroid is developed for the FRO dwell gate.
- e. The measured angle is equal to the product of the time difference between TO and FRO centroid and applicable system constants.

NOTE: The dwell gate processing used in the receiver is not explicitly required to process the MLS signal format. It is included to suppress the effects of out-of-beam multipath.

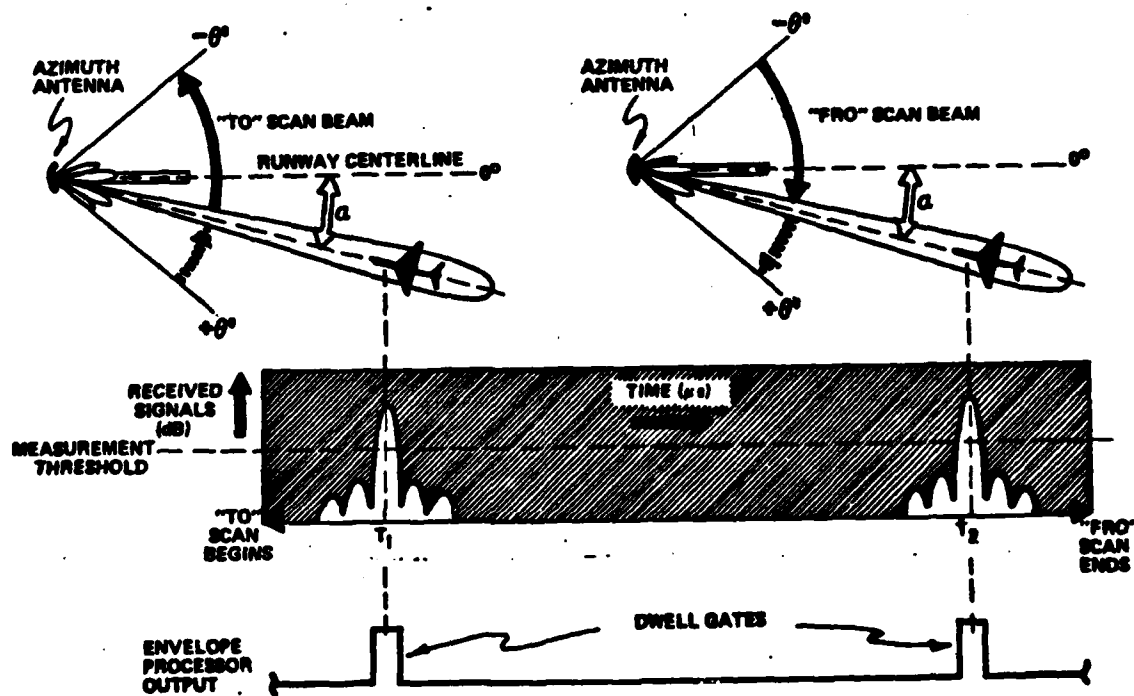
The remaining TRSB signal format consists of 15 kilobit DPSK data, except for Sidelobe Suppression (SLS) data, and Left-Right (L/R) guidance data which are transmitted during a specific preamble bit period as measurable signal "levels" without regard to phase data. Time synchronization of the airborne system with the ground system is reestablished for each TRSB function with the Barker Code after the airborne system establishes carrier frequency and phase lock with the ground system during the acquisition section of the preamble. System utilization of the remaining TRSB data format will be described during the discussion of the angle receiver design in Section 4.

The airborne system operation is compatible with operation from any of the several MLS configurations since airborne system operation is keyed to operation on individual functions of the MLS TRSB signal format.

The BN system is designed to provide proportional guidance inside an azimuth coverage range of ± 40 degrees about the runway centerline. Proportional guidance means that the angle receiver will provide, to course deviation indicators and flight control systems, a guidance error signal which is proportional to the difference between the selected course and the actual course.

The SC system is designed to provide a total azimuth coverage range of ± 40 degrees about the runway centerline. Proportional guidance is provided only inside the central ± 10 degree sector, while sector guidance is provided elsewhere inside the ± 40 degrees total coverage.

ANGLE MEASUREMENT TECHNIQUE



- TIME DIFFERENCE $T_2 - T_1$ RELATES DIRECTLY TO MEASURED ANGLE α
 - MICROPROCESSOR CALCULATES ANGLE
- GATES PROVIDE FOR MULTIPATH/INTERFERENCE DISCRIMINATION
 - COMPARE RECEIVED POWER INSIDE GATES/OUTSIDE GATES FOR CONFIDENCE
 - TRANSIENTS OCCURRING OUTSIDE GATES ARE REJECTED TO PRESERVE CONFIDENCE
- SAME TECHNIQUE APPLIES TO ALL ANGLE FUNCTIONS, INCLUDING 360° AZIMUTH
- THRESHOLD SETTING/ANGLE MEASUREMENT IS INSENSITIVE TO RECEIVED SIGNAL LEVEL

FIGURE 2-31. ANGLE MEASUREMENT TECHNIQUES

Left-right guidance (sector guidance) is provided outside the proportional guidance region to achieve performance similar to the ILS clearance function. It is obtained by specially shaped ground antenna patterns and by the transmission of two guidance pulses in the signal format (Figure 2-27) following the function preamble. The aircraft angle receiver can determine if it is in the left or right sector by comparing amplitude of the fly-left with the fly-right pulse. Appropriate guidance commands can then be provided to the pilot. When the aircraft is within ± 40 degrees of runway centerline, but outside the range of proportional guidance, the CDI deflection will be full scale left or right. Within the range of proportional guidance, the CDI deflection will be proportional to off-course deviation (from the course selected).

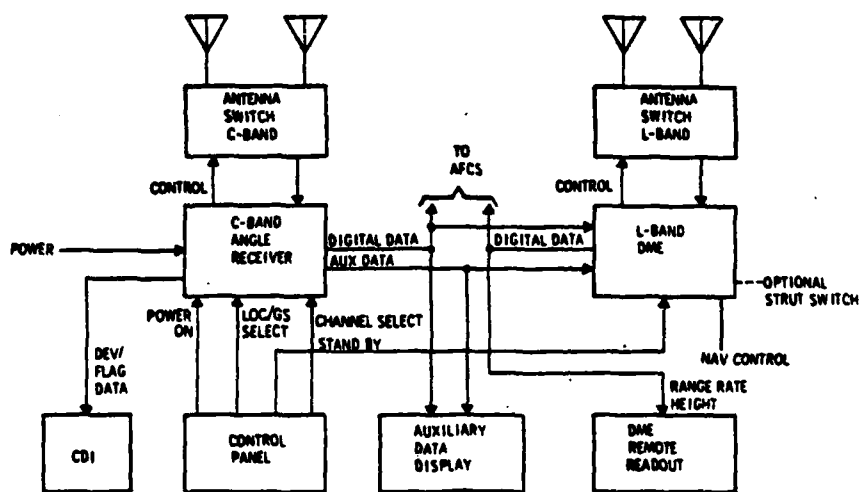
The SC and the BN angle receivers utilize identical signal processors to promote module commonality. Hence, the receiver output is established by the facility configuration. That is, a SC or a BN configured aircraft flying into a BN facility will have proportional guidance over a range of ± 40 degrees azimuth. Also, either aircraft configuration flying into a SC facility will have proportional guidance over ± 10 degrees azimuth and left-right sector guidance elsewhere in the ± 40 degrees azimuth sector.

The BN avionics system block diagram is shown in Figure 2-32, and sketches of the BN avionics equipments are shown in Figure 2-33. The corresponding SC avionics equipments are shown in Figure 2-34. The BN system is functionally described below. The block diagram and operation of the SC system is essentially identical to that of the BN system, except that in the SC system the DME is omitted and no auxiliary data is displayed.

The C-Band TRSB signals are received by the antenna(s) which are located on the aircraft to provide the required pattern coverage. On aircraft with long cable runs between the antenna and angle receiver, an optional preamplifier may be used to preserve system sensitivity. When more than one antenna is used, the received signal is routed to the antenna switch which is controlled by angle receiver logic. The angle receiver utilizes the "antenna select" time period of the azimuth function format to sample each antenna output signal level and selects the antenna with the largest signal level after consistency of data has been established.

The selected antenna output is then routed to the angle receiver which provides the following functions:

- a. Its RF/IF circuitry amplifies the received signal at the selected MLS frequency channel, filtering out adjacent and other undesired signals.



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FIGURE 2-32. BASIC NARROW A/B EQUIPMENT BLOCK DIAGRAM

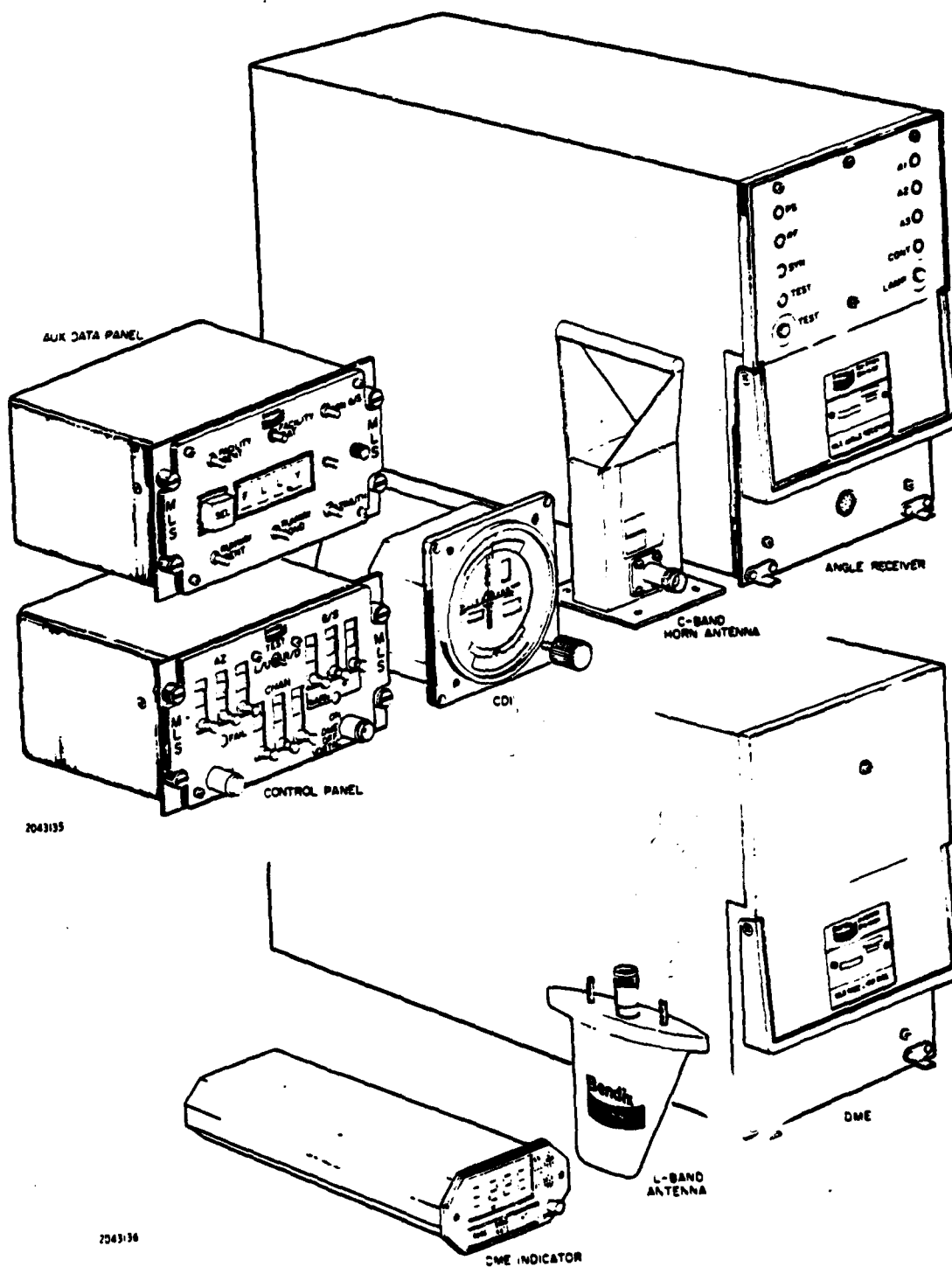


FIGURE 2-33. BASIC NARROW AIRBORNE EQUIPMENT

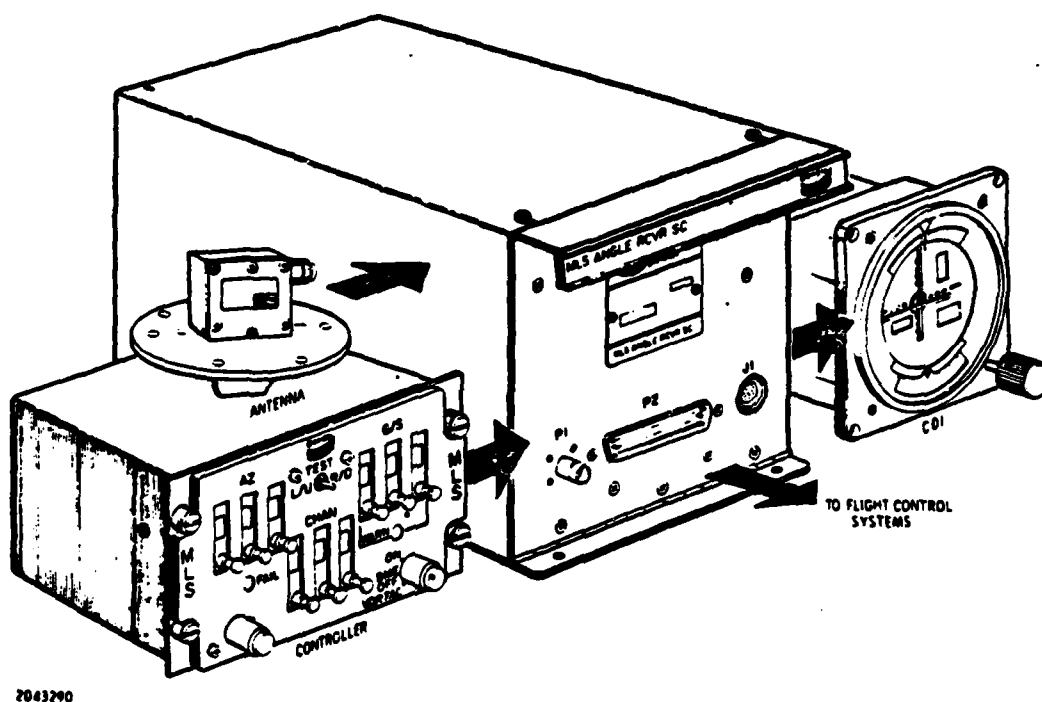


FIGURE 2-34. SMALL COMMUNITY AIRBORNE EQUIPMENT

- b. The DPSK decoder establishes phase and frequency lock with the ground transmissions on the first four bits of the preamble, then establishes time synchronization with the ground transmission through the Barker code.
- c. Having established time synchronization, bits 9 through 15 of the preamble are decoded to establish identification of the function received.
- d. Having established function identification and time synchronization, the processor is instructed to perform its established routines of preparing angle measuring circuitry to anticipate the TO/FRO scanning beams and of examining the remainder of the preamble bit by bit and performing its appropriate actions of decoding Morse code facility identification, calculating the azimuth deviation scale factor, measuring the amplitudes of the left/right clearance beam, comparing the levels of the sidelobe suppression circuit to the envelope peak amplitude to prevent tracking on side lobes, and comparing minimum selectable glide slope to actual selected glide slope.
- e. Convert the scanning beam envelope to dwell gates (see Figure 2-33), measure angles, and develop tracking gates.
- f. If the received function is a basic or auxiliary data word, it too is detected by the angle receiver after preamble decoding to achieve frequency and time synchronization and proper function identification.
- g. Before outputting any results, check data for validity and consistency. Validity is checked by a series of time measurements on the TO/FRO pair, including pulse width and TO/FRO symmetry. Consistency is measured by a long term (up to 20 sec) average of comparisons between signal amplitudes inside and outside the tracking gate.

In summary, the basic functions of the angle receiver are to measure azimuth and elevation angles and to output course deviation data in analog form and to output in digital form actual measured azimuth angle with respect to runway centerline and measured elevation angle with respect to zero elevation angle. The analog data is used for display on course deviation indicators and analog flight control systems. The digital data is used in

TABLE 2-30. ANGLE RECEIVER SPECIFICATION

CHARACTERISTIC	DESCRIPTION
Operating Frequency	5031.00 to 5090.70 MHz
Number of Channels	200
Channel Spacing	300 kHz
Frequency Stability (Long Term Stability 1 yr.)	+50 kHz max. (10 PPM)
Channel Bandwidth	+75 kHz min.
Adjacent Channel Separation	-60 dB min.
Spurious and Image Rejection (min.)	
A. Below 4750 MHz	75 dB
B. Above 5350 MHz	75 dB
C. 5130 to 5350 MHz	70 dB
D. 4750 to 5000 MHz (Image)	70 dB
E. 5000 to 5130 MHz (All Channels except Adjacent)	75 dB
Type of channel selection	2 out of 5
Type of Localizer and Glide Slope Selection	Serial Binary
Max. Signal Input (Mixer Burnout)	
A. CW	+20 dBm
B. Pulse	+40 dBm
Noise Figure	10 dB max.
Tangential Sens.	-103 dBm min.
Dynamic Range (1 dB Linearity)	75 dB min.
LO Radiation Out Antenna Port	-50 dBm
Acquisition Time	1 sec
Polarization	Vertical
Power Requirements	115 VAC and 28 VDC

digital flight control systems where measured data can be compared to external reference data, such as curved path data, for automatic guidance purposes. Digital elevation angle is also used by the DME interrogator in its height calculation routine. Decoded auxiliary data is routed to the auxiliary data display. A summary of the angle receiver performance criteria is shown in Table 2-30.

The L-Band DME interrogator function is to provide range, range rate, and height data to the aircraft indicators and control system. The interrogator transmits a coded pulse pair to the ground DME transponder which, after a fixed delay, retransmits a coded pulse pair to the interrogator which computes range on a basis of measuring round trip time, less fixed delay time. By measuring change in range over a predetermined time interval, range rate is calculated. In conjunction with elevation angle and facility geometry data, height is calculated. The interrogator contains its own time synchronization and will output data after "tracking" with the transponder has been established and data acquisition and validation criteria have been satisfied. The interrogator can function in a normal L-band enroute DME mode for RNAV, or in a precision MLS mode where the ranging accuracy is improved from +600 feet to +76 feet. Mode switching from "enroute" to "precision" is automatic and is keyed to measured range. A summary of DME performance criteria is presented in Table 2-31.

The DME indicator provides for a switch selectable readout of range, range rate or height with resolution to MLS precision requirements.

The interrogator and the angle receiver are controlled by the common control panel which provides for selection of MLS azimuth heading, elevation heading, channel frequency, on-off and self-test. Outside the range of MLS coverage, the control panel can also provide for enroute L-band DME channel frequency selection. A glide slope warning light notifies the pilot when the selected glide slope is below the minimum permissible glide slope for the ground facility.

The auxiliary data display provides for a switch selectable readout of facility identification, facility category, minimum selectable glide slope, runway identification, runway condition, and azimuth heading relative to runway centerline.

2.5.3 Installation Design

MLS avionics installation designs were performed and implemented on FAA test aircraft types CV-880, Aerocommander, and DC-6. The installation drawing package was delivered during the course of the program. The Aerocommander and DC-6 were each provided with a single-channel Small Community and a single-channel Basic Narrow system, while the CV-880 was provided with the equivalent of a dual Basic Narrow system. A typical equipment configuration is shown in Figure 2-35.

TABLE 2-31. DME INTERROGATOR SPECIFICATIONS

CHARACTERISTIC	DESCRIPTION
Operating Frequency	960 - 1215 MHz
Number of Channels	200
Frequency Control	standard 2/5
Channel Tune Time	10 ms
Transmitter Peak Power	120 Watts (nominal)
Receiver Sensitivity	-62 dBm
IF Frequency	63 MHz
IF Bandwidth	3.5 MHz
Threshold	0.2 μ sec
Acquisition Time	Less than 1 sec
Dynamic Tracking	0 - 600 Kts
Memory	1 sec
Range	0 - 30, 0 - 200 NM
Range Accuracy	\pm 76 ft
Search Time/Cycle	Less than one second
Search PRF	150 PP/sec
Track-Lock PRF	40 PP/sec
Audio Ident	50 mW, 600 ohm
Power Requirements	115 VAC 400 Hz

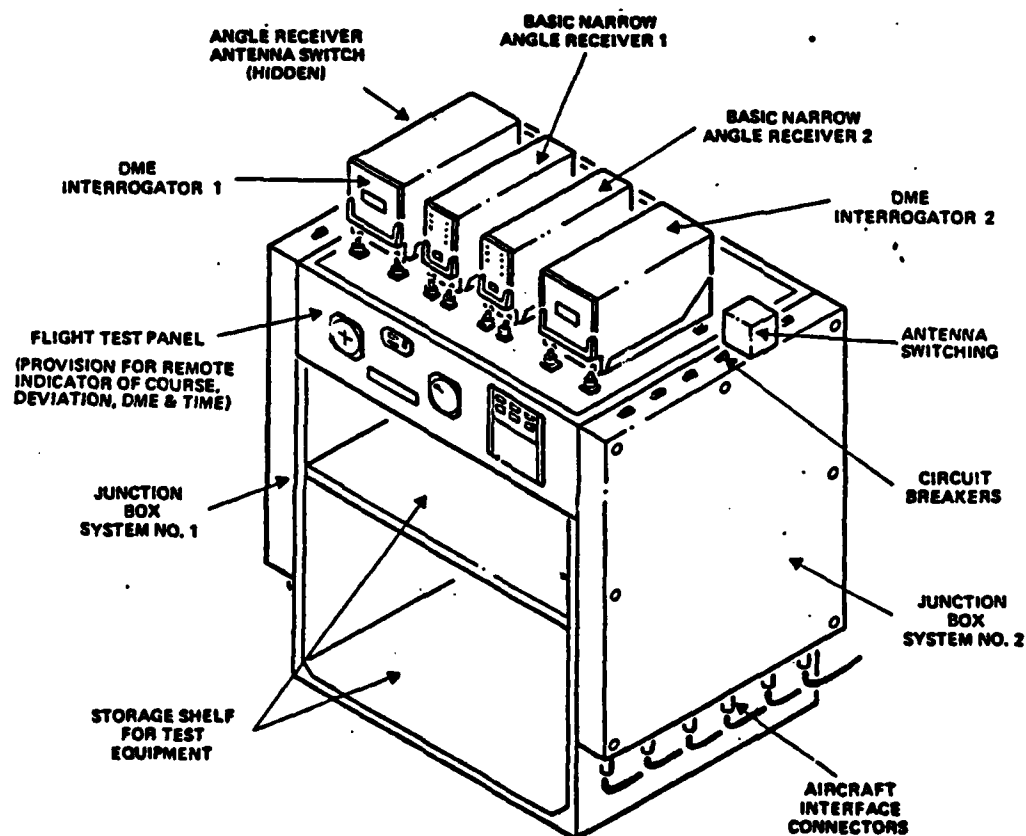


FIGURE 2-35. CV-880 MLS AVIONICS EQUIPMENT RACK LAYOUT

SECTION 3

DETAILED GROUND SYSTEM DESCRIPTION

3.1 INTRODUCTION

This section presents a detailed description of the Basic Narrow (BN) and Small Community (SC) Ground Subsystem equipments. The previous section presented information on system performance and parameters. This section continues that description by supplying information to a more detailed level on the major components of each ground subsystem. Included in the description are equipment performance and features, physical parameters, and a listing of applicable technical and maintenance manuals.

3.2 BASIC NARROW GROUND SUBSYSTEM

The BN ground subsystem description is presented in two parts, one for the AZ/DME equipment and the other for the EL equipment. The major components listed in paragraph 2.3.1 for each equipment are discussed in detail. In addition, the antenna case and equipment shelter, with their environmental controls and ancillary equipment, such as obstruction lights, lightning protection, power distribution, etc., are included.

3.2.1 Azimuth/DME Equipment

3.2.1.1 Scanning Array

3.2.1.1.1 Description - The components comprising the AZ scan array are shown in Figure 3-1. The RF signal is input to the Fine Scan Modulator which provides four outputs whose levels are controlled by a 6-bit command from the Beam Steering Unit. The scan network is a matrix of SP4T RF switches. The scan network commutates the four outputs from the Fine Scan Modulator across the 48 active inputs to the Rotman lens. The lens provides a shaped beam in azimuth whose phase front is determined by the selected inputs. The Rotman lens feeds a vertical array of slotted waveguide elements which provide the elevation shaping.

The beam is scanned (stepped) through the combined actions of the scan network and the Fine Scan Modulator. For each commutation step provided by the scan network, the beam will step approximately one beamwidth. This is referred to as a coarse scan step. Ten fine scan steps (0.1 beamwidth) are provided for each coarse scan step by varying the output levels from the Fine Scan Modulator. This is described more fully in paragraph 3.2.1.1.4.

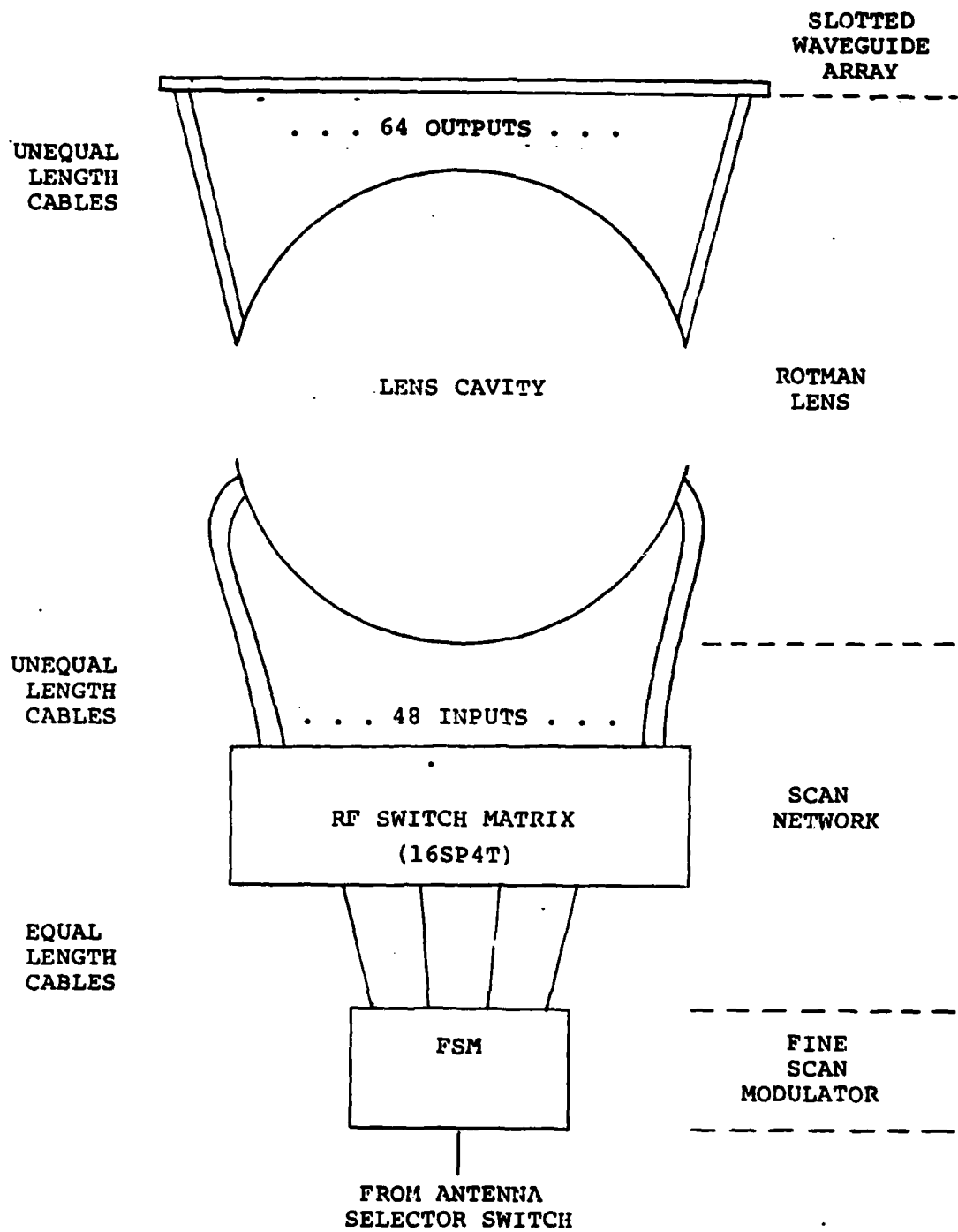


FIGURE 3-1. BN AZ SCANNING ARRAY

Front and rear views of the AZ antenna are shown in Figures 3-2 and 3-3. The AZ antenna nominal characteristics are given below:

Beamwidth	2°
Side Lobes	≤ -20 dB
No. Elements	64 active + 2 parasitic
Spacing	$0.54\lambda_0$
Start Angle	41.718°
Stop Angle	-41.718°
Fine Scan Steps	461
Gain (at FSM input)	22.6 dBi
Guidance Coverage	$\pm 40^\circ$ max., adjustable down to $\pm 10^\circ$

3.2.1.1.2 Rotman Lens - The Rotman lens is the key element in the AZ scan array. A schematic of the lens is shown in Figure 3-4. It is a parallel plate ($7/8$ " spacing), constrained lens with 56 inputs and 64 outputs. Four inputs on each end are dummy inputs used to control the effects of mutual coupling of the active inputs on either end. All inputs and outputs are SMA female connectors located on the flat surface of the lens. The lens has the property of having three perfect foci. One is on the centerline, and the other two are symmetrically located about the center focus on the focal arc at the angle α_0 . Appendix A describes the considerations that went into the design of the Rotman lenses.

The principal design parameters are G , R , F , and α_0 as defined in Figure 3-4. The focal arc has a radius of $R = 0.896$ m. The centerline distance between the focal arc and the shaped output surface of the lens is $G = 1.254$ m. The location of the two off-axis foci are defined by $\alpha_0 = \pm 40^\circ$. The distance from these foci to the center of the shaped output is $F = 1.140$ m.

The electrical lengths from the shaped output surface of the lens cavity to the linear waveguide array are a critical part of the lens design and are achieved in the AZ antenna through RF cables which connect directly to the slotted waveguide radiators.

The elements in the waveguide array are spaced 0.54λ at 5060.7 MHz, which is consistent with complete suppression of grating lobes for maximum beam positions of $\pm 42^\circ$ from boresight

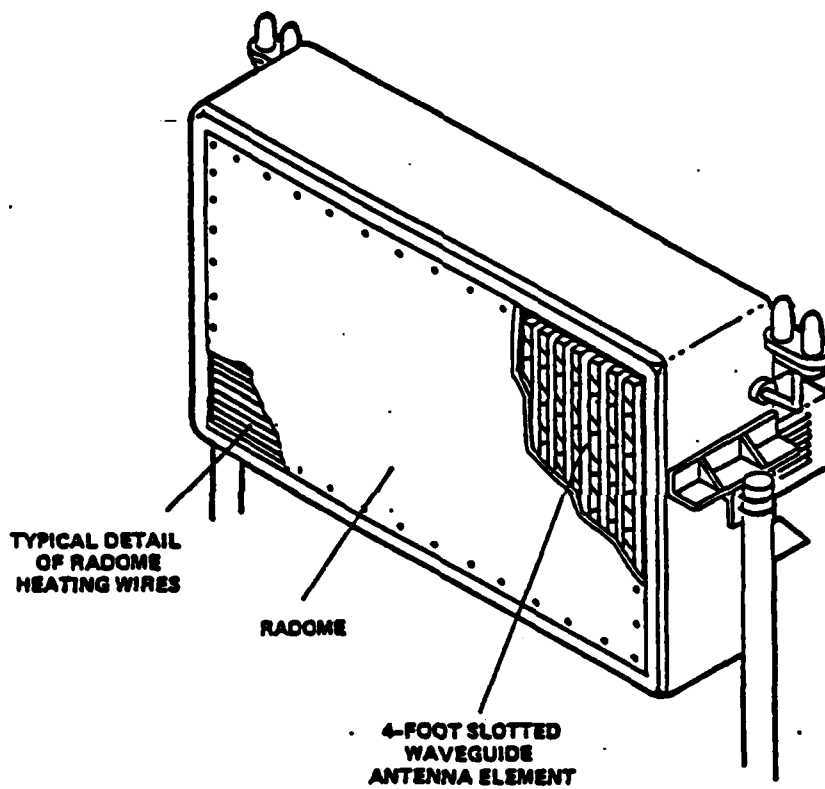


FIGURE 3-2. BASIC NARROW AZ ANTENNA
MAJOR COMPONENTS, FRONT VIEW

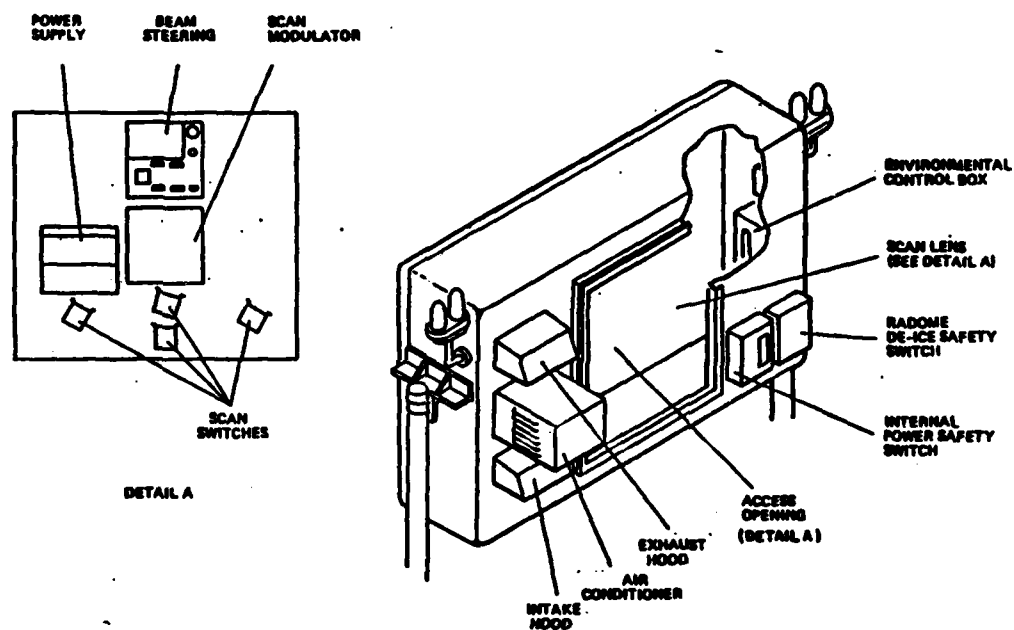
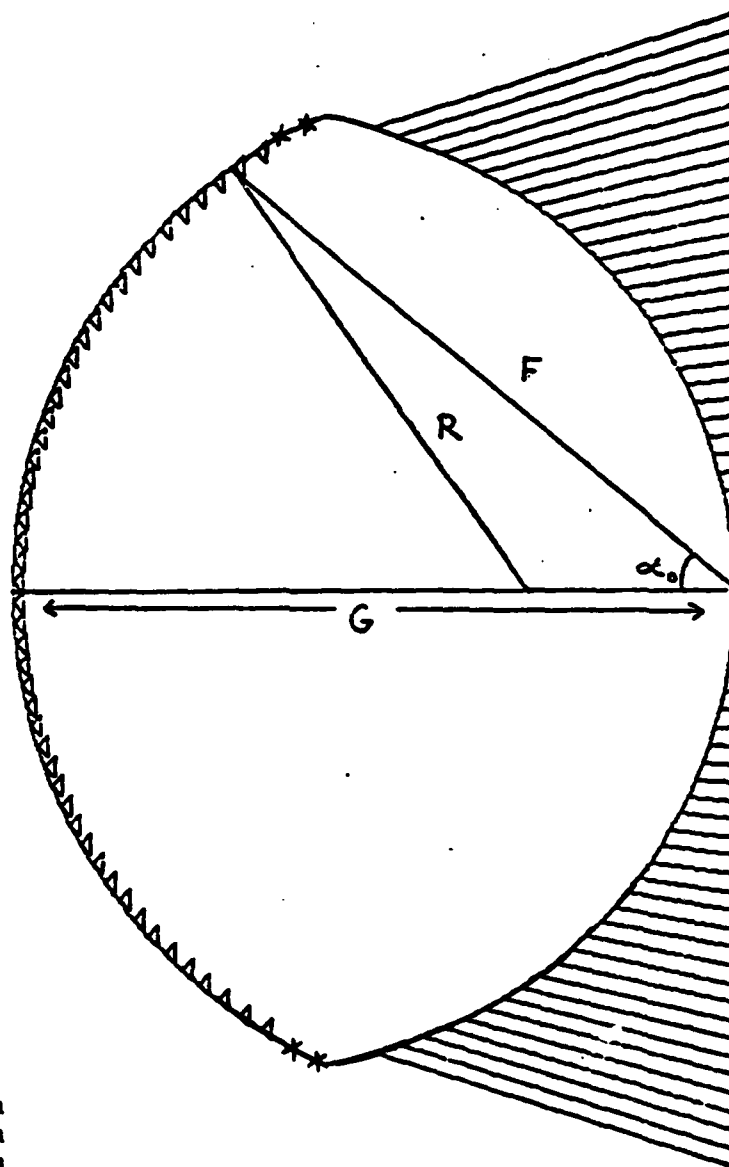


FIGURE 3-3. BASIC NARROW AZ ANTENNA
MAJOR COMPONENTS, REAR VIEW

48 ACTIVE
INPUTS



64
ELEMENTS

$$\frac{d}{\lambda} = 0.54$$

$F = 1.140\text{m}$
 $G = 1.254\text{m}$
 $R = 0.396\text{m}$
 $\alpha_0 = 40^\circ$

FIGURE 3-4. BN AZ ROTMAN LENS

over the frequency band. This maximum scan position permits the trailing 3 dB point of the beam to scan through the $\pm 40^\circ$ sector required for proportional guidance.

The lens inputs are variably spaced, with the closest spacing at the center of the focal arc. This is done for the following reason. When a single input at an angle α is excited, a beam is formed in space at an angle α from the array normal. The array illumination from any one input is essentially uniform, forming a beam with -13 dB side lobes. Since side lobes on the order of -20 dB are desired, it is necessary that the illumination be shaped. This is achieved by exciting three inputs for each beam position, the three inputs being spaced to provide three orthogonal beams in space. The excitation amplitudes are adjusted to provide a cosine illumination over the aperture, resulting in a theoretical sidelobe level of -23 dB. By making the input probe positions proportional to $1/\cos \alpha$, this orthogonality is maintained over the entire scan region.

Figure 3-5 is a composite of the measured patterns of the AZ antenna showing every 10th beam in the step scan sequence. The dotted line is the element pattern of one of the centrally located waveguide elements.

3.2.1.1.3 Scan Network - A schematic of the scan network is shown in Figure 3-6. It includes four equal length cables from the Fine Scan Modulator to the first tier of four SP4T switches, twelve equal length cables from the first tier of SP4T switch outputs to the second tier of twelve SP4T switches, and 48 unequal length cables from the SP4T switches to the lens inputs. The 48 cables are used to equalize the electrical lengths from the outputs of the SP4T switches to the center of the shaped output surface of the lens. This is necessary in order to maintain phase equality of the orthogonal beams used to form the radiated pattern.

With this scan matrix, it can be seen that the four inputs from the Fine Scan Modulator can be commutated, one input at a time, from one end of the input array to the other and back again, providing the TO/FRO scan motion. By this means, the coarse scan steps mentioned in paragraph 3.2.1.1.1 are obtained. The fine scan steps will be described in the following paragraph.

The switches are modular, comprised of an RF section and a driver section. The RF section contains five SMA female connectors for input/output, stripline transmission line, four PIN diodes, and a sensor comprised of a built-in coupler and detector for each RF output. The driver section includes circuitry to accept the input commands, and to output the RF

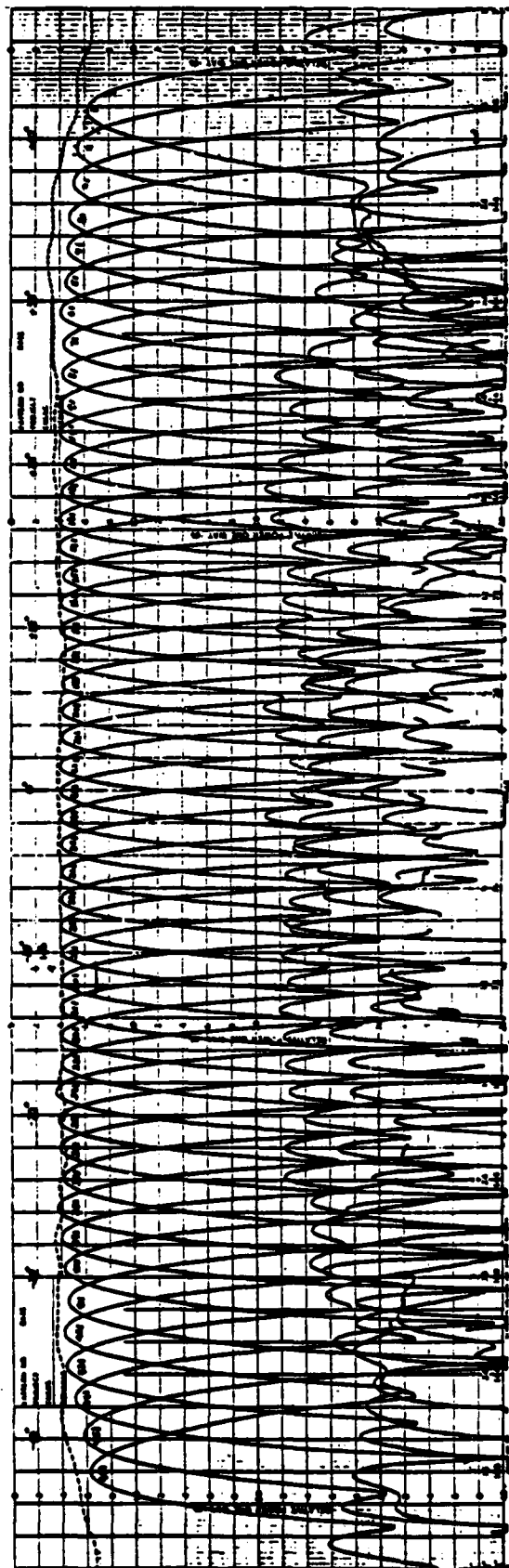


FIGURE 3-5. BASIC NARROW AZ ARRAY, AZIMUTH PATTERN
 EVERY 5th BEAM FROM $+40^\circ$ to -40°
 DOTTED CURVE IS TYPICAL ELEMENT PATTERN

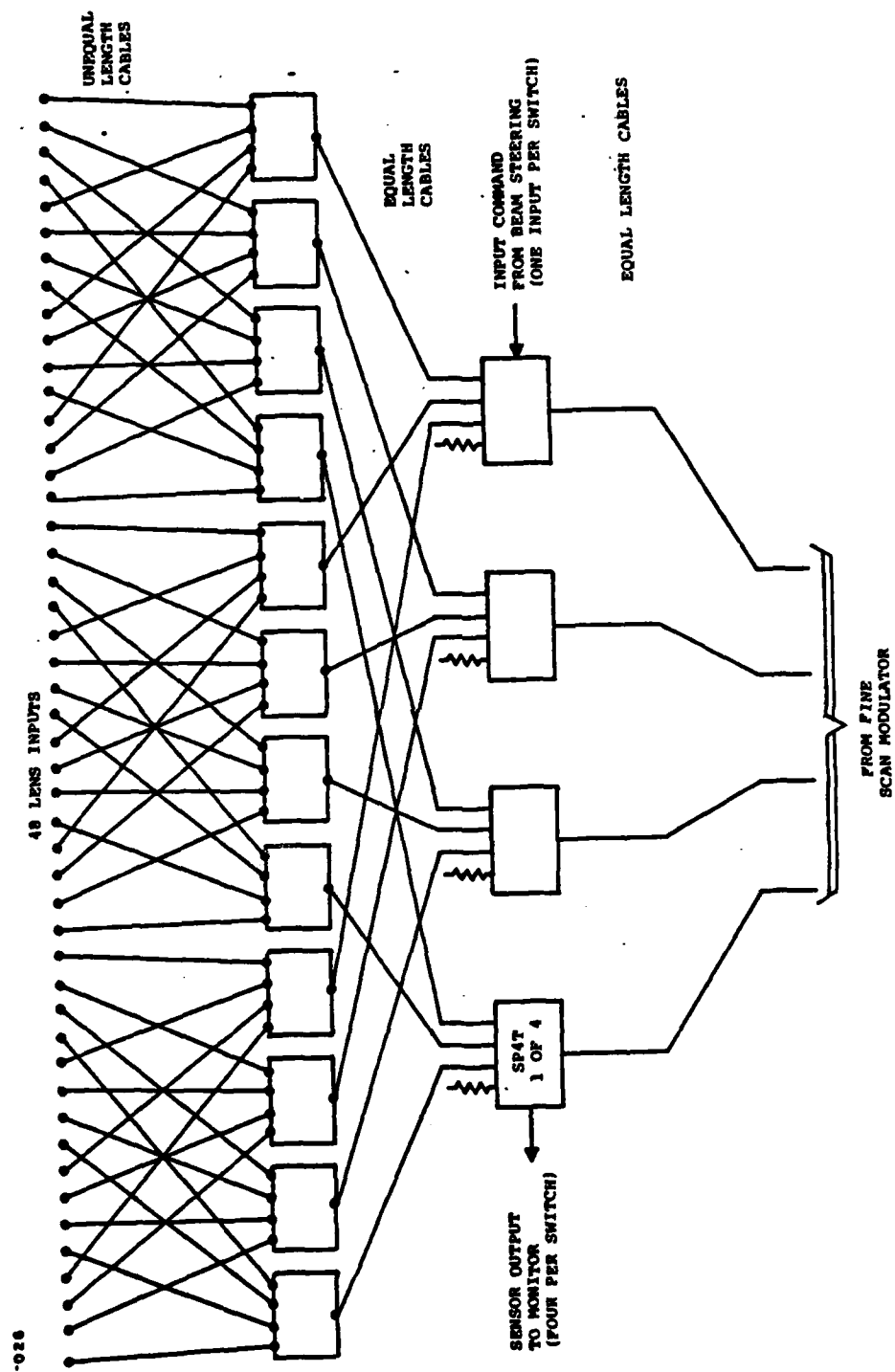


FIGURE 3-6. SCAN NETWORK

sensor signals. The characteristics of the switches are listed below:

Frequency Range	5030-5091 MHz
Input RF Power	15 watts maximum, load VSWR = 1.5:1 at 20 percent duty factor
VSWR	1.25 maximum for all ports (all output ports matched for all switch states)
Insertion Loss (max.)	1 dB
Isolation (Port-to-Port) (min.)	30 dB
Switching Time	0.5 to 1.0 μ sec
Switching Rate	5 kHz peak rate with 20 percent duty
Phase Variation Output-to- Output	± 5 deg
Phase Variation Switch-to- Switch	± 5 deg
Electronic Inputs	Beam Steering Unit (2 lines) +5VDC (2 lines) -40VDC (2 lines)
Electronic Outputs	Monitor (4 lines)
Input Impedance	50 ohms
Monitoring	Video output level 600 mV, into 1K ohm impedance for 1-watt rf input power
Spurious and Harmonic Generation	-60 dB or more
Maximum Overload Con- ditions	a. 15 watts peak, 3 watts average with VSWR = infinity at any phase b. 15 watts CW for 10 milli- seconds with VSWR = infinity at any phase c. 15 watts CW for 1 second with VSWR = 2:1 at any phase
Isolated Output Reflected Power	Isolated (OFF) positions of switch capable of dissipating 10 watts peak power at 1-watt average

3.2.1.1.4 Fine Scan Modulator - A schematic of the fine scan modulator (FSM) is shown in Figure 3-7. It is constructed entirely in waveguide. The input and outputs are type N female. As seen from the figure, it is composed of three identical sections, each section containing a magic tee power divider, two 6-bit ferrite phase shifters (most significant bit = 45°), and a sidewall quadrature hybrid.

The operation of the FSM can be deduced by considering the properties of one section. The two outputs of a section can be represented by the matrix equation.

$$E_o = E_h E_i \quad (3-1)$$

$$\text{where } E_i = \text{input excitation} = \begin{bmatrix} e^{j\alpha} \\ e^{-j\alpha} \end{bmatrix}, \quad -\pi/4 \leq \alpha \leq \pi/4$$

$$E_h = \text{hybrid scattering matrix} = \begin{bmatrix} 1 & e^{j\pi/2} \\ e^{j\pi/2} & 1 \end{bmatrix}$$

$$E_o = \text{output levels} = \begin{bmatrix} E_1 \\ E_2 \end{bmatrix}$$

Solving equation (3-1), the output powers are

$$P_1 = P_o (1 + \sin 2\alpha)$$

$$P_2 = P_o (1 - \sin 2\alpha)$$

$$2P_o = \text{input power}$$

Thus, as α varies from $-\pi/4$ to $+\pi/4$, either output varies from no (or full) power to full (or no) power or any level in between, subject to the constraint of the least significant bit of 1.4°. Additionally, the two outputs will remain in-phase at a value that is independent of the phase shifter settings.

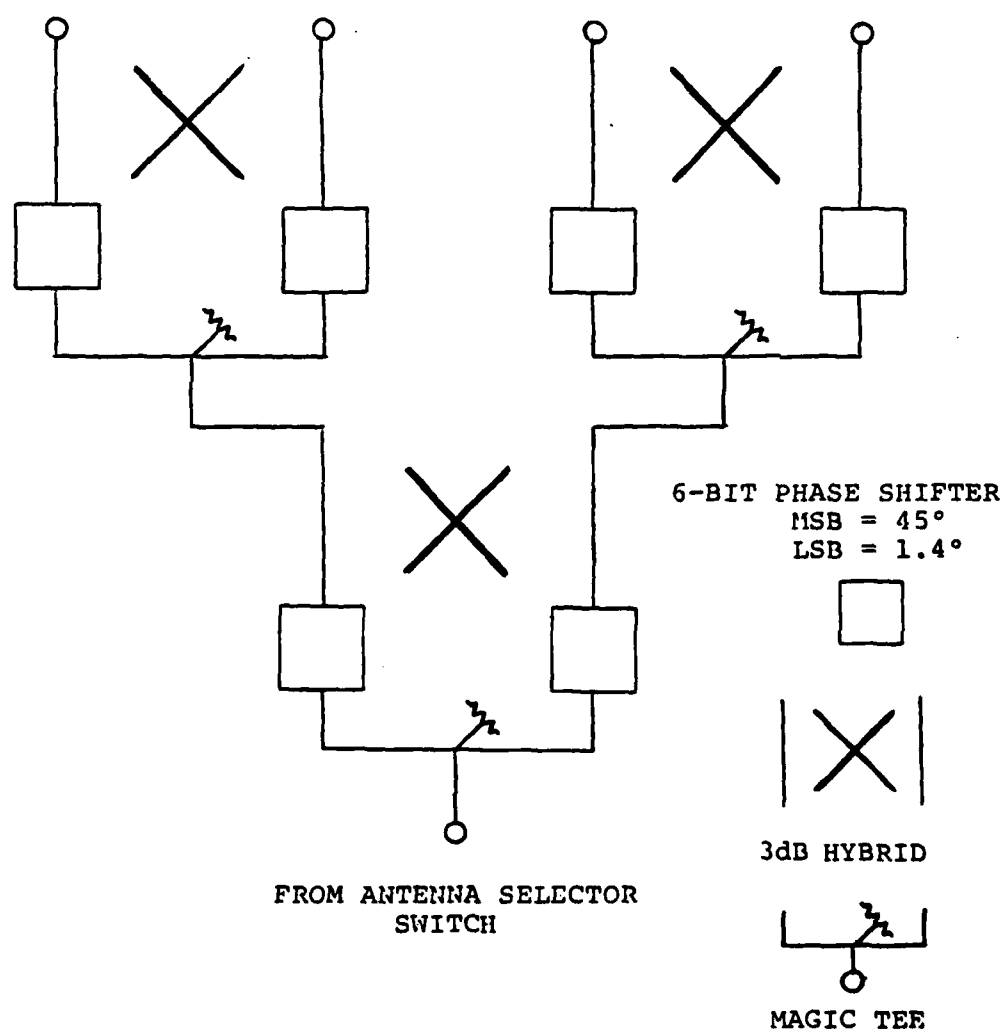


FIGURE 3-7. FINE SCAN MODULATOR

Considering the FSM as an ensemble of three of these sections, and denoting the \pm phase settings of each section as α , β , γ , the four output powers are proportional to

$$\begin{aligned} P_1 &= (1 + \sin 2\alpha) (1 + \sin 2\beta) \\ P_2 &= (1 + \sin 2\alpha) (1 - \sin 2\beta) \\ P_3 &= (1 - \sin 2\alpha) (1 + \sin 2\gamma) \\ P_4 &= (1 - \sin 2\alpha) (1 - \sin 2\gamma) \end{aligned}$$

Now, consider the application of the FSM to obtaining the fine scan steps mentioned previously. To do this, we must refer to the orthogonal beams generated by each lens input. Two adjacent feed probes equally excited will produce a beam in space with a theoretical -23 dB first sidelobe level. This beam is the superposition of two orthogonal $\text{sinc}(x)$ ($\sin x/x$) beams. The shape of this antenna pattern (array factor) is given by

$$F(x) = \frac{\cos x}{1 - \left(\frac{2x}{\pi}\right)^2}$$

The beam amplitude has been normalized to unity at its nose, and the variable x represents the sine angle variable conventionally used when computing line array patterns. The distance between the first nulls of the $\text{sinc}(x)$ patterns is normalized to 2π for simplicity. The angular extent between the first nulls of each $\text{sinc}(x)$ is $2\lambda/D$ in sine angle space (D = radiating aperture) and the adjacent $\text{sinc}(x)$ beams are separated by one-half of this, or λ/D . This two-probe excitation produces a cosine voltage illumination function across the radiating aperture. More efficient illuminations can be produced, but would require a larger number of excited probes.

Now the sampling theorem can be used to establish the weights required to produce a shifted version of this same beam shape. Figure 3-8 illustrates the sampling concept. The sampling theorem says that the $F(x)$ function can be exactly reproduced by summing an infinite number of $\text{sinc}(x)$ functions spaced by π and weighted according to the $F(x)$ function. These $\text{sinc}(x)$ functions can all be arbitrarily shifted under the original $F(x)$ function so long as they remain equally spaced. A good approximation of the $F(x)$ function can be obtained by assuming all sample values are zero, except the one located under the main lobe of the $F(x)$ function. The sacrifice in truncating the samples is a slight variation of beam shape as a function of sample location. The equations for the three sample values are given by equation (3-2):

$$w_{1i} = \cos z_i / \left[1 - \left(\frac{2z_i}{\pi} \right)^2 \right]$$

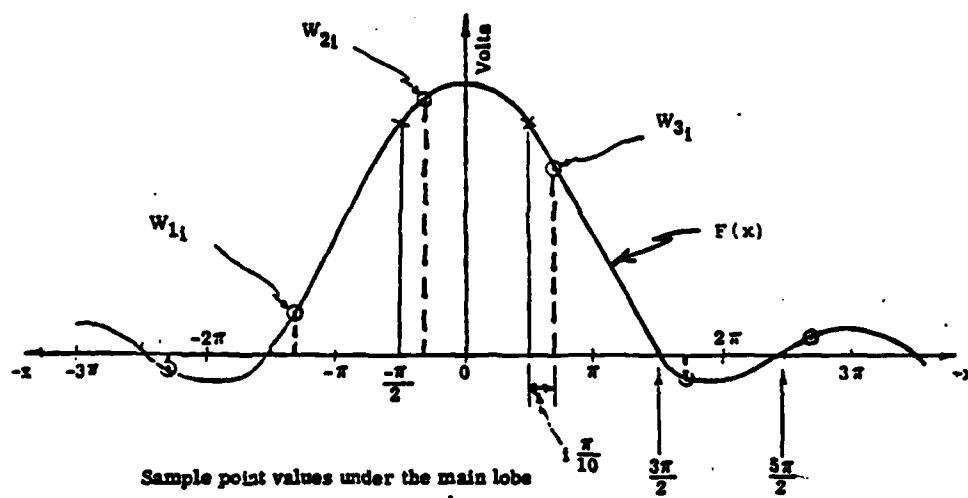


FIGURE 3-8. FEED PROBE EXCITATION WEIGHTS
DETERMINED FROM SAMPLING THEOREM

$$W_{2i} = \cos (Z_i \div \pi) \left/ \left[1 - \left\{ \frac{2(Z_i + \pi)}{\pi} \right\}^2 \right] \right. \quad (3-2)$$

$$W_{3i} = \cos (Z_i \div 2\pi) \left/ \left[1 - \left\{ \frac{2(Z_i + 2\pi)}{\pi} \right\}^2 \right] \right.$$

$$Z_i = -\frac{3\pi}{2} + i \frac{\pi}{10}, \quad i = 0, 1, 2, \dots, 10$$

When $i = 0$ or 10 , the equations for W_2 and W_3 become indeterminate. The values are: $W_{20} = W_{210} = W_{30} = W_{310} = \frac{\pi}{4}$.

There can be no less than two, nor more than three, samples under the main lobe at any one time. The above discussion indicates that the $F(x)$ function can be produced by samples weighted according to those values given by equation (3-2). It follows directly from the above that, if three adjacent feed probes of the Rotman lens are weighted in proportion to the sample values given, the $F(x)$ beam shape will result. As the set of three weights is changed according to the index " i ", the beam will move in sine angle space while maintaining its nearly constant shape, gain, and sidelobe levels. Ten different sets of three voltage weights are computed, permitting the beam to scan in $1/10$ probe spacing steps.

The quantitative effect of truncating the number of feed probes to a maximum of three can be seen by noting the gain variation and beam peak motion as a function of the index " i ". The resulting effect on dynamic angle accuracy is to produce a small cyclic error whose period is equal to the probe spacing angle. Estimates of the peak cyclic dynamic pattern oscillation due to truncation indicate a peak fluctuation of less than ± 0.03 of the feed probe separation angle.

The mechanism of stepping the beam in $1/10$ beamwidth steps can now be seen with the aid of Figure 3-6. Assume all switches are in the "1" position so that the first four lens inputs are connected to the four FSM outputs. If the first two outputs are equally excited and the other two are zero, then a beam will be formed at an angle corresponding to the midpoint between inputs 1 and 2. Now let the first output decrease to zero, while the third increases until outputs 2 and 3 are equally excited. There will now be a beam formed at the angle corresponding to the midpoint between inputs 2 and 3. This cycle is repeated until inputs 3 and 4 are equally

excited. At this time, the status of the switches are changed so that output 1 is connected to input 5. The FSM is then cycled until outputs 1 and 4 are equally excited, and so on until inputs 46 and 48 are equally excited at the end of the scan.

Since the spacing between lens inputs is slightly less than one beamwidth, stepping the FSM in 10 steps between states where two outputs are equally excited will produce a fine scan step of less than 0.1 beamwidth.

If the FSM is cycled at regular time intervals, the beam motion will be uniform in sine angle space. To obtain uniform motion in angle space, the FSM is cycled at a variable rate. This is discussed further in paragraph 3.2.1.5.

The FSM assembly is contained within a RF tight enclosure and includes RF and drive circuitry. The FSM is controlled by a 6-bit parallel input word from the beam steering. This 6-bit word allows up to 64 different output power levels to be specified; only 40 are used during the fine scan sequence, and these are defined in Table 3-1. The input command is distributed to three ROM's, one for each RF section in the FSM. The ROM outputs control the drive circuitry of the six phase shifters. A monitoring circuit is included which outputs a signal when any phase shifter bit fails. In order to meet the stringent phase and amplitude requirements over the MLS temperature range, the ferrite phase shifters are maintained at a constant temperature by heating elements. The FSM characteristics are listed below:

Frequency	5031.0 - 5090.7 MHz
Impedance	50 ohms
RF Power	30 watts CW maximum
Absorption Loss (max.)	1.2 dB
VSWR (max.)	1.2:1
Output Phases	± 5 deg
Output Powers	40 different power ratios
Switching Time (max.)	≤ 1 microsecond
Switching Rate	Maximum rate of 133.3 kHz with a 20 percent duty cycle
Digital Input and Output	6-bit parallel digital word

TABLE 3-1. FSM POWER DIVISIONS

POWER SETTING	OUTPUT 1 (-dB)	OUTPUT 2 (-dB)	OUTPUT 3 (-dB)	OUTPUT 4 (-dB)
0	3.01	3.01	Infinity	Infinity
1	3.96	2.23	27.81	>30
2	5.16	1.63	20.72	>30
3	6.59	1.21	16.28	>30
4	8.32	0.96	13.00	>30
5	10.41	0.87	10.41	>30
6	13.00	0.96	8.32	>30
7	16.28	1.21	6.59	>30
8	20.72	1.63	5.16	>30
9	27.81	2.23	3.96	>30
10	Infinity	3.01	3.01	Infinity
11	>30	3.96	2.23	27.81
12	>30	5.16	1.63	20.72
13	>30	6.59	1.21	16.28
14	>30	8.32	0.96	13.00
15	>30	10.41	0.87	10.41
16	>30	13.00	0.96	8.32
17	>30	16.28	1.21	6.59
18	>30	20.72	1.63	5.16
19	>30	27.81	2.23	3.96
20	Infinity	Infinity	3.01	3.01
21	27.81	>30	3.96	2.23
22	20.72	>30	5.16	1.63
23	16.28	>30	6.59	1.21
24	13.00	>30	8.32	0.96
25	10.41	>30	10.41	0.87
26	8.32	>30	13.00	0.96
27	6.59	>30	16.28	1.21
28	5.16	>30	20.72	1.63
29	3.96	>30	27.81	2.23
30	3.01	Infinity	Infinity	3.01
31	2.23	27.81	>30	3.96
32	1.63	20.72	>30	5.16
33	1.21	16.28	>30	6.59
34	0.96	13.00	>30	8.32
35	0.87	10.41	>30	10.41
36	0.96	8.32	>30	13.00
37	1.21	6.59	>30	16.28
38	1.63	5.16	>30	20.72
39	2.23	3.96	>30	27.81

3.2.1.1.5 Vertical Waveguide Array - The AZ array aperture is a planar array of 64 active and 2 dummy elements (one at each end), using edge slotted WR 159 waveguide. The elements are mounted vertically on an aluminum honeycomb panel, with an interelement spacing of 0.54λ . The 32 radiating slots are cut in the narrow wall and extend slightly over into the broad wall. The slots are at varying angles in an alternating pattern from top to bottom. The elements are all identical, except there is a right and left version used in adjacent positions along the array. This is done to reduce mutual coupling, to reduce the slot tilt angle for a given coupling, and to reduce cross-polarization. Cross-polarization is below -25 dB throughout coverage.

The array elements are fed from the top through a female SMA connector. A load terminates the lower end of the waveguide element.

Figure 3-9 is a drawing showing a portion of the azimuth array. The slot alternating pattern is evident in this figure. Between each element are quarter wavelength shorting strips. The shorting strip acts to reduce mutual coupling variation and to prevent slow waves across the aperture. Figure 3-9 also illustrates how the elements are fed with alternating probe orientation to maintain phase coherence.

Amplitude is controlled by the amount the slot is tilted, slot resonance is achieved with the depth the slot cuts into the broad wall, and phase is controlled by the vertical spacing along the waveguide.

Figure 3-10 shows a measured elevation pattern. The azimuth patterns were shown previously in Figure 3-5.

Other characteristics for this element are:

VSWR	$\leq 1.2:1$
Efficiency	>80 percent
Gain (at nose in array)	≥ 13.8 dB
Polarization	Vertical
Cross-Polarization	<-25 dB
Underside Slope	>8 dB/degree

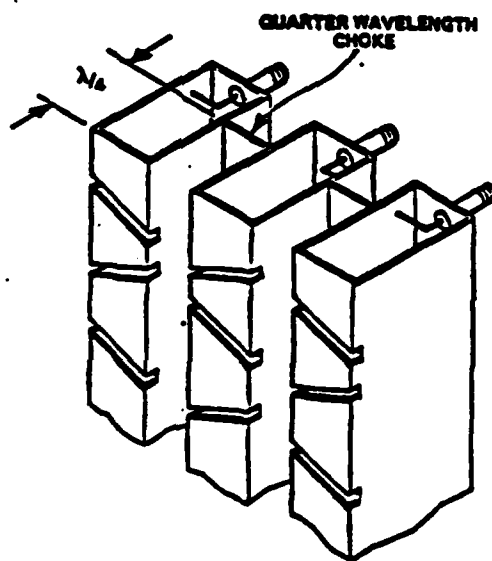


FIGURE 3-9. ALTERNATING ELEMENT SLOT PATTERN
WITH COMPENSATING ALTERNATING FEED PROBES

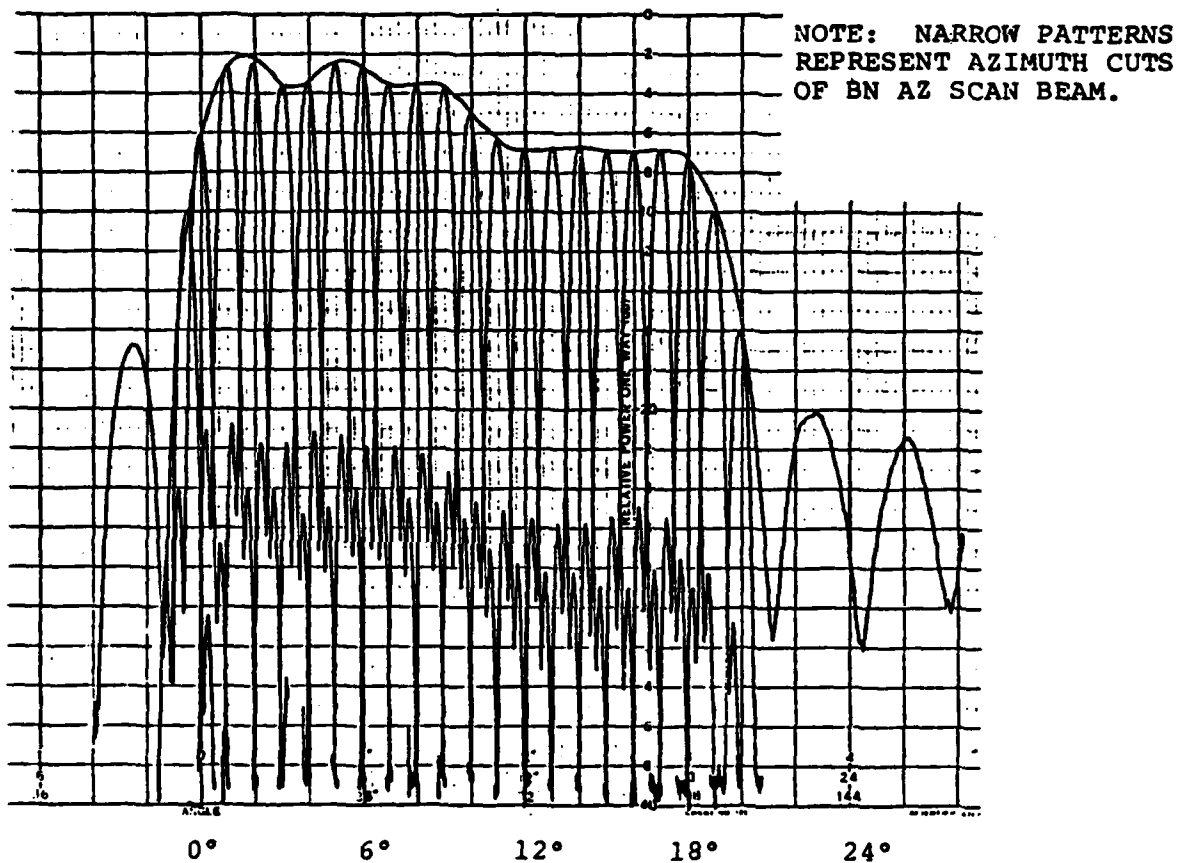


FIGURE 3-10. ELEVATION PATTERN OF:

Basic Narrow AZ Scanning Beam
Right and Left SLS
Forward Ident
Small Community AZ Scanning Beam
Right/Left/Rear SLS
Forward Ident
Left/Right Clearance
Beams

3.2.1.2 Forward Ident Antenna - The forward ident antenna consists of a single vertical slotted waveguide radiator that is identical to the elements in the azimuth array. It is mounted on a shaped ground plane and has a heated fiberglass radome. The measured azimuth and elevation patterns are shown in Figures 3-11 and 3-10 respectively. Maximum gain is 16.2 dBi. This same antenna is used for the Basic Narrow EL and Small Community AZ and EL forward ident antennas.

3.2.1.3 SLS Antenna - The two sidelobe suppression antennas are identical to the forward ident antenna except for the addition of a thin vertical wire stretched in front of the radiating slots to broaden the pattern. The two antennas are bore-sighted at $+110^\circ$ in azimuth. A measured pattern is shown in Figure 3-12. As is evident from the figure, these two antennas provide complete azimuth coverage outside the $+40^\circ$ proportional guidance sector. Maximum gain is 13.5 dBi. This same antenna is also used for the Small Community AZ SLS antennas.

3.2.1.4 Antenna Selector Switch - The antenna selector switch is a modular SP4T RF switch comprised of an RF section and a driver section. The RF section consists of five type N female connectors for input/output, stripline transmission lines, and four PIN diodes. The driver section includes circuitry to accept the input commands and actuate the diodes. The characteristics of the antenna switch are listed below.

Frequency Range	5025 - 5095 MHz
RF Power Rating	"Hot" switching up to 30 watts (CW) average rf
Insertion Loss from Common RF Input to Selected RF Output Port	≤ 1.25 dB
Isolation between Common RF Input and Unselected RF Output Ports and between Output Ports	> 45 dB
Switch Speed	2 microseconds, measured from 50 percent point on leading edge of selection input signal to 90 percent point on detected rf envelope of rf output port
Switching Rate	For all ports, 150 transfers per second; for any one port, 50 transfers per second

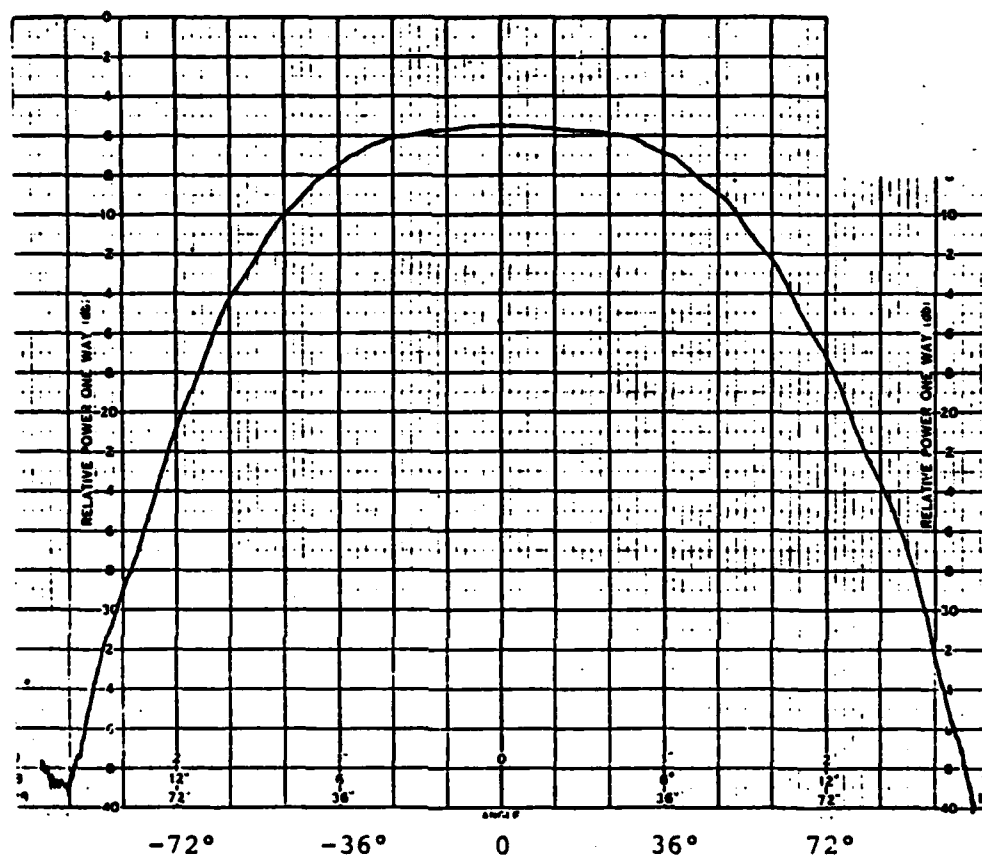


FIGURE 3-11. FORWARD IDENT ANTENNA AZIMUTH PATTERN FOR:

Basic Narrow EL
 Basic Narrow AZ
 Small Community EL

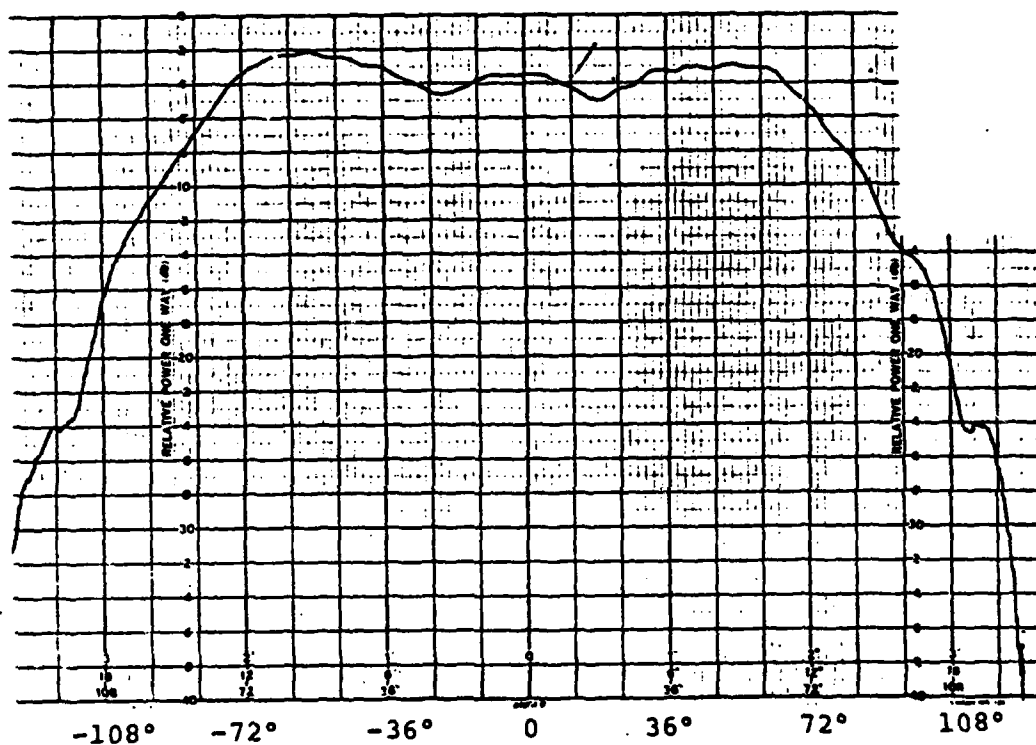


FIGURE 3-12. TYPICAL SLS AZIMUTH PATTERNS FOR:
 Basic Narrow
 Small Community

RF Impedance	Nominal 50 ohms, input and output
Output Load VSWR	$\leq 2:1$, any phase
Input VSWR	$\leq 1.25:1$, any phase
Transients	≤ 0.2 V peak
EMI Performance	≥ 80 dB up to 40 GHz

3.2.1.5 Beam Steering - The beam steering equipment provides control signals to the scan network switches and the Fine Scan Modulator which steer the antenna beam in the required azimuth TO-FRO sequence. This equipment is mounted on the backside of the Rotman lens. A block diagram of the beam steering equipment is shown in Figure 3-13. Functionally, this equipment can be divided into two sections, control and monitor. The control section develops the signals which actually control the beam scan while the monitoring section develops duplicate on-line signals and compares the two sets of signals to ensure that proper steering control is being achieved.

3.2.1.5.1 Control Section - The scan control, scan switch driver, and the intermediate scan switch driver comprise the control section. The scan sequence is controlled by the scan and pause gates; that is, the TO scan continues until terminated by the end of scan. The left and right maximum beam scan radiation limits are independently adjustable by controlling the transmitter on-off switching, thereby resulting in an RF scan which can be less than the electronic scan. The electronic boresight alignment and the timing between the TO-FRO scan is achieved by controlling the start of the scan gate. The pause gate terminates the TO scan and inhibits the scan for a predetermined period of time and then starts the FRO scan.

The fine count, used for the 0.1 beamwidth scanning increments, is derived by dividing the 10-MHz clock down to 100 kHz. The coarse count of 10 kHz, used for the 2-degree scanning increments, is derived via a further 10:1 division.

To compensate for the scan being non-linear with angle as the beam is steered away from the centerline of the runway, the 100 kHz boresight frequency must be modified for each coarse scan position. Assuming position 24 corresponds to the center of the runway, each beam position between 24-48 and 24-0 gets a frequency compensation factor inserted into the nominal 100 kHz frequency. This provides a constant 20,000 degree/second scan.

A PROM circuit is used in the scan control board to develop the switching sequence for the 12 upper tier scan network switches. The first four switches are driven directly from the scan control board. The other eight switch signals are applied to the scan switch driver for the corresponding driving circuits. The 6-bit binary coarse count developed in the scan control is applied to a PROM circuit in the intermediate scan switch driver. This PROM circuit develops the proper switching sequence for the lower tier of four switches. To provide better noise immunity, differential drivers are used to drive the switch transmission lines. Therefore, each differential driver transmits two signals (A and B) on four lines to an associated differential receiver at each of the 16 scan switches.

The scan control also generates the 6-bit signal which controls the fine scan modulator.

The 10-MHz oscillator is accurate to 1 part in 10^6 over the temperature range from -20°C to $+70^{\circ}\text{C}$.

3.2.1.5.2 Monitor Section - The scan control monitor, scan control comparator, scan switch RF monitor, intermediate scan switch RF monitor, and the two scan switch RF monitor expanders comprise the monitor section. The intermediate scan switch RF monitor and the two scan switch RF monitors form a part of the scan switch monitor function. The scan control monitor is similar to the scan control in that many of the same signal types are generated. These signals are used throughout the Beam Steering and Monitor assembly for monitoring by comparing these signals with signals generated by the scan control. The comparison for these signals is accomplished in the scan control comparator.

There are three monitor signals generated and fed to the executive monitor: (1) antenna scan switch RF monitor, (2) scan modulator monitor, and (3) scan electronics monitor. To provide better noise immunity, differential line drivers are used to drive these interfacing monitor signal transmission lines. The antenna scan switch monitor signal is developed by monitoring the rf energy out of the scan switches. Four sensor signals, one signal for each scan switch output jack, are developed for each of the 16 scan switches. These signals are OR'ed and multiplexed to form a composite signal which is sent to the executive monitor as the antenna scan switch monitor. The status of each phase shifter bit of the fine scan modulator and the phase shifter heater are monitored and OR'ed internally. Therefore, the scan modulator monitor signal is developed in the scan modulator and then applied directly to the Beam Steering and Monitor assembly, from where it is sent to the executive monitor. The scan electronics monitor signal, which

is fed to the executive monitor, provides an overall check of the antenna control system. This signal is developed by OR'ing the comparator circuits for the following five separate monitoring functions:

- a. Fine scan modulator control input: This 6-bit binary number originates in the scan control. Duplicate signals are developed in the scan control monitor. The two groups of signals are then compared in the scan control comparator to form a single monitoring signal.
- b. Driver signals for the first four upper tier scan switches: These 16 lines originate in the scan control. Duplicate signals are developed in the scan control monitor. The two groups of signals are then compared in the scan control comparator to form a single monitoring signal. Driver signals for the other eight upper tier scan switches are developed from the same PROM as those for the first four switches, but use separate line drivers. The line driver outputs are compared to the inputs.
- c. Driver signals for the four lower tier scan switches: These 16 lines originate in the intermediate scan driver. Duplicate signals are developed and compared in this same circuit with the originating driver signals to form a single monitoring signal.
- d. Nominal 100 kHz count frequency: This signal is developed in the scan control and a duplicate signal is developed in the scan control monitor. These two signals are compared in an exclusive OR circuit to form a single monitoring signal.
- e. 10-MHz clock: The 10 MHz crystal oscillator output is monitored in the scan control monitor to determine if logic-level 10 MHz signals are present.

In addition to these interfacing monitoring signals, which, when activated, shut down the system, there are several other monitoring circuits which activate fault indicators locally in the scan control comparator and monitor. These monitoring circuits include a fault indicator for each of the scan switches, a composite scan switch error fault indicator, a 10-MHz clock fault indicator, and fault indicators for the scan modulator, nominal 100 kHz, scan electronics, and a scan control fault indicator which monitors the scan modulator input and the drivers for the first four upper tier switches.

The scan switches are monitored sequentially during each antenna scan. If a faulty switch is discovered, the associated switch fault indicator is activated, the monitor clocks are inhibited, and a fault is indicated. Thus, the faulty switch can be easily identified. A scan monitor gate inhibits the monitoring of the switch sensor signals during any portion of the scan interval where the RF energy is turned off to avoid erroneous fault indications.

3.2.1.6 TWT Amplifier - The TWT amplifier is a Litton Model 653. Amplification is obtained with a Litton L-5559-06 traveling wave tube. Within the amplifier, the TWT is followed by an isolator and a 6 GHz low pass filter. The characteristics of the TWT amplifier are listed below:

Power Input:	102 to 130 V @ 57 to 63 Hz
Operating Frequency:	5.031 to 5.092 GHz
Saturated Power Output:	20 Watts Minimum CW, 30 Watts Maximum CW
Gain at Saturated Power Output:	45 dB Minimum
Noise Figure:	35 dB Maximum
Spurious and Harmonic Signals:	-60 dBc
Output Noise:	-65 dBc, 1 kc bandwidth more than 5 kHz from carrier
Power Output Stability:	With a fixed RF input, the saturated power output will not change more than ± 1 dB over the temperature range of -10°C to $+60^{\circ}\text{C}$.
Amplitude Modulation:	Power output will remain within ± 0.1 dB over a 150 micro-second period.
Input and Output Impedance:	50 Ohms
Connectors:	RF - Type N Female Power - AMP 201298-3 Female

The TWT amplifier will output a fault signal when the TWT is over temperature, when the helix current is excessive, or when the beam supply voltage is excessive. This fault signal is not sent to the monitor subsystem, but activates a light on the TWTA panel.

3.2.1.7 RF Unit - The prime function of the RF unit is to generate the modulated C-band signals which are amplified by the TWT amplifier. It is a rack mounted drawer and contains a C-band exciter and amplitude and bi-phase modulators. A block diagram of the RF unit is shown in Figure 3-14. The prime frequency source is a crystal oscillator. This is multiplied by 50 in the C-band exciter. The bi-phase modulator controls the DPSK encoding of the RF signals. The amplitude modulator turns the RF signal on and off in response to commands from the Local Control/Status unit. A variable attenuator in the output of the amplitude modulator is used to control the drive level to the TWT amplifier.

3.2.1.7.1 C-Band Exciter - The exciter consists of an oven controlled crystal oscillator, an X25 frequency multiplier, a voltage controlled cavity oscillator (VCO) and an X2 frequency multiplier.

The crystal oscillator frequency is multiplied X25. A transistor driven coaxial cavity oscillator is used in a phase-lock-loop to amplify the signal and maintain frequency stability. The output of the VCO is multiplied X2 by a high efficiency varactor multiplier.

The exciter generates a highly stable C-band cw signal in the band of 5031.0 MHz to 5090.7 MHz. It contains a crystal oscillator operating at 1/50 of the C-Band frequency. The C-band output of the exciter is phase locked to a harmonic of the crystal oscillator frequency. The crystal frequency is used by the monitor system to monitor site frequency.

The output power of the exciter is monitored through a directional coupler in the bi-phase modulator.

Performance characteristics of the exciter are listed below:

Output Frequency Range	5031.0 to 5090.7 MHz
Crystal Oscillator Frequency	1/50 of output frequency
Frequency Stability	1 part in 10^9 per 100 ms short term, ± 10 kHz long term (6 mos)
Spurious Signals	≥ 50 dB below carrier
Output Noise	≥ 63 dB below carrier measured over 1 kHz band centered at output frequency
Power Output	≥ 20 mW

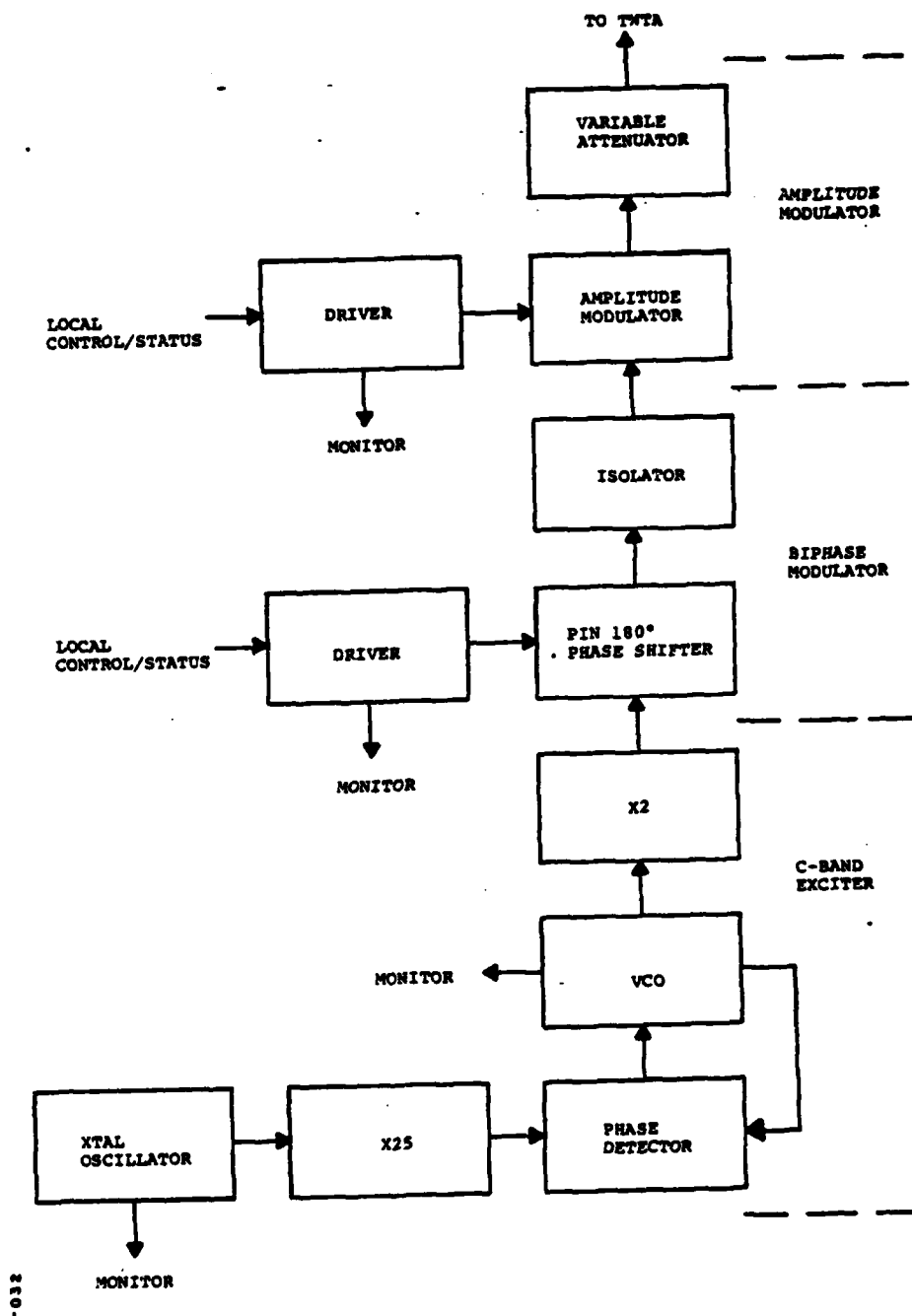


FIGURE 3-14. RF UNIT BLOCK DIAGRAM

Power Stability	+0.1 dB in 150 μ s short term +1 dB long term
Output Impedance	50 ohm

3.2.1.7.2 Biphase Modulator - The biphase modulator is a 180 degree pin diode stripline phase shifter and driver which performs biphase modulation (DPSK encoding) on the C-band carrier.

The biphase modulator contains two subassemblies, a stripline assembly and a driver circuit.

The stripline assembly is the RF portion of the modulator. It contains the 180 degree phase shifter and three directional couplers. The C-band signal from the exciter passes through a 25 dB directional coupler and a 13 dB directional coupler before entering the 180 degree phase shifter. The 25 dB coupler output is a test point to measure exciter frequency and power when testing or troubleshooting. The 13 dB coupler is used to monitor exciter power output.

The phase shifter is a hybrid coupled type utilizing two PIN diodes. The phase of the output of the phase shifter shifts 180 degrees when the PIN diodes are switched from a forward biased to a reversed biased state or vice versa.

The phase modulated signal leaving the phase shifter passes through a second 13 dB directional coupler which is used as a test point to monitor biphase modulation and power.

The RF assembly operates at a nominal power level of 20 mW. The insertion loss is 1.8 dB nominal with a variation in insertion loss of 0.3 dB with the 0 degree and 180 degree phase states. The phase accuracy is typically 180 degrees \pm 3 degrees. The switching time is typically less than 1.0 μ s.

The driver circuit contains circuitry to forward and reverse bias the pin diodes in the phase shifter and monitor circuitry to verify that the driver is biasing the diodes in the proper direction as commanded by the input commands.

3.2.1.7.3 Amplitude Modulator - The amplitude modulator is a PIN diode stripline switch and driver which gates the C-band carrier on and off as commanded by system timing signals from the Local Control/Status Unit. The modulator shapes the carrier rise and fall times in order to control the width of the transmitted spectrum.

The amplitude modulator assembly contains two subassemblies, the stripline assembly and the driver circuit.

The stripline assembly is the RF portion of the modulator. It contains two 13 dB directional couplers, one at the input and one at the output, and a PIN diode reflective attenuator. The two directional couplers provide test points for observing the input and output of the modulator. The PIN diode attenuator has three PIN diodes, each having a stripline matching section connecting the diodes to the stripline 50-ohm transmission line. The three matching sections join the transmission line at $3/4\lambda$ spacings along the transmission line. DC blocks are located between the junctions and at the input and output of the attenuator to DC isolate the PIN diodes. When the PIN diodes are forward biased at 20 mA each, a short circuit is presented at the junctions of the matching sections and the transmission line, resulting in the C-band signal being attenuated at least 65 dB. By changing the amount of PIN diode bias current, the amount of attenuation can be changed. When the diodes are reverse biased, a high impedance is presented at the junctions of the matching sections and the transmission line resulting in minimum attenuation. The desired envelope of the C-band carrier can be generated by controlling the bias currents of the PIN diodes.

The driver circuit contains the circuitry that controls the PIN diode bias current and monitor circuitry to verify that the modulator is turning the C-band carrier on and off in response to the input commands. The attenuation characteristic of the PIN diode attenuator is such that the rise and fall characteristics of the RF envelope at the attenuator output will approximate a cosine squared characteristic. The cosine squared approximation is good from low attenuation to approximately 35 dB of attenuation.

The PIN diode driver circuit generates the exponential current function for controlling the shape of the rise and fall of the RF envelope and switches the diode current to the maximum of 20 mA per diode for maximum attenuation. When system timing commands the modulator to turn the C-band carrier on, the fast switching driver immediately switches off the maximum current to the diodes, thereby decreasing the attenuation from approximately 65 dB to 35 dB. Current through the diodes is now controlled by the exponential current generator which begins to decrease the current exponentially from approximately 4 mA to less than 0.1 mA over a time period of 14.5 μ s. As a result of this process, the RF is turned on from maximum to minimum attenuation and the RF envelope during turn-on will have an approximate cosine square characteristic. When system timing commands the modulator to turn the C-band carrier off, the

exponential current generator begins to increase the diode current exponentially to approximately 4 mA over a time period of 14.5 μ s. After 14 μ s, the RF has been attenuated approximately 35 dB and the fast switching driver immediately switches high current through the diodes, resulting in maximum attenuation of the RF carrier. As a result of this turn-off process, the RF envelope will have an approximated cosine squared characteristic as the RF is attenuated.

The monitor circuitry performs three functions. First, it verifies that the exponential current generator circuit is operating in response to input commands. Second, it verifies that the fast switching, high current driver is operating in response to input commands and that no diode is open. Third, it verifies that the RF is not on for longer than approximately 10 ms. No MLS transmission is on longer than 10 ms. The three monitor outputs are OR'd to provide a single output to the system monitor.

The variable attenuator is a coaxial, manually controlled unit mounted on the RF unit rack. It is used to adjust the drive level to the TWT amplifier to approximately 1 mW.

3.2.1.8 Local Control Status - Both the AZ and EL subsystems contain a Local Control/Status equipment which functions as the subsystem control and interface unit. The AZ and EL Local Control/Status assemblies differ basically in that the EL contains less electronics (no Aux Data), and the timing circuits are different to accommodate the different format.

Due to the similarities in the AZ and EL equipments and their functions, only the AZ Local Control/Status will be described below. When the EL equipment is different, the difference will be noted. The Local Control/Status equipments provide the major functions listed in Table 3-2.

A simplified functional block diagram of the AZ Local Control/Status equipment is shown in Figure 3-15. Those functions not contained in the EL subsystem are identified by having the upper right hand corner of the function block blacked in.

The station identification code, which is transmitted from the AZ site for identifying the site and its location, is generated within the AZ Local Control/Status assembly. This code is different for each MLS configuration. The Morse Code Generator provides the necessary flexibility for making changes to the code. The identification code is monitored via the Morse Code monitor.

TABLE 3-2. MAJOR FUNCTIONS OF BASIC NARROW
LOCAL CONTROL/STATUS

MAJOR FUNCTION	AZ	EL
Morse code monitoring and generation	X	-
Status lamps to indicate control and system status	X	X
Interference and control between monitor and transmitter	X	X
Data link for subsystem	X	X
Data link for DME	X	-
Automatic subsystem restart	X	X
Subsystem running time meter	X	X
System sync	X	-
Data link for variable Aux data	X	-
Fixed Aux data	X	-
Basic data/DPSK	X	X
Subsystem timing generation	X	X
Timing control	X	X
Master clock (10 MHz)	X	X

All of the status lamps for both AZ and EL are mounted on a PC board with the light emitting diode (LED) protruding through holes in the front panel. These lamps provide an indication of (1) the ON/OFF status of the subsystem, (2) if the automatic restart is in process of recycling, or if it has tried and failed, (3) the positions of the controls (LOCAL or REMOTE), (4) the subsystem operation mode (fully operative or test mode), and (5) dc power operation.

Whenever the maintenance monitor detects an executive error in the subsystem, it is handed over to the Local Control/Status assembly which in turn shuts the subsystem down. (It should be noted that with the AZ subsystem "down" there will be a loss of system sync which results in the complete system being "down".) After 50 seconds in the down state, the Local Control/Status assembly will automatically attempt to bring the subsystem back on the "air". This is accomplished by resetting the maintenance monitor acquiring the sync and once the sync is established as being correct the subsystem is placed back on the "air" with control being turned back to the maintenance monitor. If the maintenance monitor does not detect a fault within ten seconds, the subsystem will remain "up" until the next executive error is detected. If, however, the original error has not been cleared after ten seconds, the subsystem will go "down" again. The subsystem will then wait four additional minutes (approximately five minutes from the initial down state) and then attempt to reinstate itself a second time via the same process as described for the fifty-second period. If the subsystem fails to stay "up" for the ten-second period on this attempt, it will resort to the "failed" mode and remain "off" the air, making no further automatic attempts to reinstate itself. The subsystem is then restored to service via a manual operation, after the fault has been cleared.

The data link for both the AZ and the DME subsystems and the EL subsystem are located in the Local Control/Status assemblies. For the AZ and EL, the data is collected from information existing directly within the Local Control/Status assembly. Data link information associated with the DME is transferred from the DME cabinet into the AZ Local Control/Status assembly and then installed on the data link system. A running time meter, located on the front panel, records the operating time in hours and tenths of hours.

Sync for the entire MLS configuration is developed within the AZ Local Control/Status assembly and distributed to the subsystems via a landline. The fixed auxiliary data is generated in the Local Control/Status assembly along with word

verification, parity check, and the I.D. information that goes along with each word. The basic data word is generated in the Local Control/Status assemblies, but the word verification for the basic data word is accomplished within the Maintenance Monitor assembly. If an error is detected in the basic data word, it will produce a maintenance error and cause the associated fault lamp located on the maintenance monitor panel to light. The variable auxiliary data, generated within the AZ Remote Control/Status assembly, is transferred to the AZ Local Control/Status assembly via the data link which has a time space in its format especially designed to handle this type of data. The variable auxiliary data ASCII code is verified in the AZ Local Control/Status assembly prior to transmission from the AZ site.

The master clock oscillator which is used to establish subsystem timing is located within the Local Control/Status assembly. This clock has a frequency of 10 MHz and stability of 1 part in 10^{-9} per day. It is from this clock that 1-MHz and 15-kHz clocks are derived for the timing and DPSK data.

The complete timing for each subsystem, as well as the sync for all of the associated subsystem, is generated within the Local Control/Status assembly. The timing is accomplished in 100-nanosecond or greater increments, and the DPSK data is based upon a 15-kHz clock (66.6667 microseconds). The timing signals and timing waveforms are generated with discrete logic, partly through the use of PLA's (Programmable Logic Array), and outputted via line drivers.

3.2.1.9 Monitor

3.2.1.9.1 General - Each critical piece of equipment in the AZ subsystem provides one or more signals which are sent to the monitor equipment for processing. Paragraph 2.3.5 described the use of these signals. In this section, the generation of these signals will be discussed. The executive monitors will be discussed first (refer to Table 2-17).

Due to the similarity between the AZ and EL monitoring, the description will apply to either; when differences exist, they are specifically called out.

3.2.1.9.2 Executive Faults - The field monitor for AZ is used to check beam accuracy, beam ERP, and test pulse accuracy. This monitor checks overall site performance and is not just an indication of antenna subsystem performance. Many failures occurring in the antenna subsystem will be indicated as a beam accuracy or beam ERP failure. However, other failures in the ground electronics equipment will also cause beam accuracy and

beam ERP indications. Generally, when antenna subsystem failures cause beam accuracy or ERP indication, other antenna subsystem faults will also be indicated. The ERP measurement is made by sampling the peak power in the beam as it scans past the field monitor horn. The measurement is made using an RF detector and a video amplifier at the field monitor horn. Processing of the video is accomplished by the monitor subsystem within the electronics equipment shelter. The beam accuracy measurement is made by sampling the RF energy of the TO-FRO beams at the field monitor horn, and sending this sample back to the monitor subsystem at the electronics equipment shelter for processing.

Within the antenna subsystem, there are three executive monitors on the scanning beam antenna (see paragraphs 3.2.1.1 for AZ and 3.2.2.1 for EL): (1) scan switch monitors, (2) fine scan modulator monitor, and (3) scan control monitor. Each scan switch on the lens assembly (4 for EL and 16 for AZ) is fully monitored using an integral RF detector diode/probe at each switch output (4 per switch). At the proper time, the output video from this diode is sampled and compared to a predetermined threshold. The logic for controlling the switch monitors is contained in the beam steering assembly. For a given antenna, a single transistor-transistor-logic (TTL) signal is transmitted from the antenna subsystem to the electronics equipment shelter indicating the combined status of the switches. An indication of the failed switch by number is presented via a light-emitting diode (LED) in the switch monitor located in the Beam Steering Electronics subassembly.

The fine scan modulator has an integral monitor which checks the status of each phase shifter bit within the modulator. A single TTL signal output to the Beam Steering Electronics subassembly indicates the status of the fine scan modulator. This single output also indicates the status of the heaters within the fine scan modulator. A fault will be indicated if the heater circuit opens or, at initial turn-on, until the unit reaches the required operating temperature.

The Beam Steering Electronics subassembly is fully monitored via duplication and comparison of beam steering functions. A single failure indication (SCAN CONT) is transmitted to the monitor subsystem within the electronics equipment shelter. (See Figures 3-13 for AZ and 3-28 for EL.)

In the EL antenna, the ERP monitors on both the forward Ident and upper SLS antenna (contained at the Elevation Antenna case) are executive monitors. The radiated power at the aperture of these antennas is sampled, RF detected, video amplified, and sent to the Maintenance Monitor subsystem within the Elevation equipment shelter for processing. In the AZ antenna, these ERP

sector antenna monitors are located on the Azimuth equipment shelter.

Errors in the preamble are detected by comparing the serial DPSK data, collected by the sampling probe in the Forward Ident antenna aperture, with equivalent digital data generated independently by the DPSK monitor. Data bit mismatches are detected and segregated into several classifications leading to executive or maintenance fault indications. A mismatch in either the Barker code, ID code, or the data will produce an executive fault indication unless the ID code indicates that Basic or Auxiliary Word Data is being transmitted. In this case, a mismatch in the Barker or ID codes produces an executive fault indication; a mismatch in the data word produces a maintenance fault indication.

To monitor site frequency, use is made of the 10-MHz clock signal and the exciter oscillator output signal, which is the final frequency divided by 50. This circuitry operates at a 15 kHz offset representing zero frequency.

The beam accuracy and test pulse accuracy are measured in a similar manner. Samples of the TO/FRO beam are supplied by the field monitor, and samples of the test pulses are supplied by the Forward Ident antenna aperture probe. These outputs are monitored by thresholding the detected RF and counting the number of precision clock pulses between the leading edge of the TO beam (or first test pulse) and the trailing edge of the FRO beam (or second test pulse). This count is compared to an anticipated count. The error is provided as an 8-bit word for pointing error (0.004 degree resolution for AZ, 0.002 degree for EL), or a 5-bit word for test pulse spacing.

The DME equipment contains its own monitoring circuitry (see paragraph 3.2.1.11.2). A discrete GO/NO-GO signal is sent to the AZ monitor. The monitor develops the timing and strobe/gating for exclusive use in the monitor independently of the rest of the antenna site electronics. It is driven via the common frame sync and 10-MHz signals at each antenna site. To assure that the long chain of monitor timing decade counters continues to function, a detector at the output is used to determine that the counter chain is counting continuously. If the chain is interrupted, a GO/NO-GO is developed.

3.2.1.9.3 Maintenance Faults - The maintenance monitors for both the AZ and EL antenna enclosures are the antenna case temperature, +5 VDC power supply, +24 VDC power supply, and -40 VDC power supply. A thermistor element is used to sense temperature, and a temperature alarm is indicated at the monitor subsystem at the electronics equipment cabinet when the temperature exceeds either

+50 degrees C or -10 degrees C. All power supply voltages are sensed and sent to the equipment shelter for processing.

The generation of a maintenance fault for Basic Data Words No. 1 and No. 2 and for Auxiliary data was described in the previous section.

In the electronics shelter, the +5 volt, +15 volt, -15 volt, and +20 volt power supplies are monitored. Since the monitor subsystem has its own power supplies, these are also monitored and include two +5 volt supplies, a +15 volt supply, and a -15 volt supply.

The temperature in the electronics shelter is monitored similarly to the antenna enclosure temperature. Internal monitors within the RF unit (Section 3.2.1.7 for AZ, 3.2.2.7 for EL) provide the status of the exciter output, the amplitude modulator, and the phase modulator.

The TWT amplifier has a coupler at the output which samples the output power level (Section 3.2.1.6 for AZ, 3.2.2.6 for EL).

In the EL subsystem, a maintenance fault is indicated if the sync pulse is missing. In addition, EL timing is compared to AZ timing, resulting in an executive error when the difference is greater than 100 μ s.

An error in the auxiliary data causes generation of the data input fault.

3.2.1.10 Remote Control/Status and Remote Status

3.2.1.10.1 Remote Control/Status - Control of the AZ and EL subsystem at the Local Control/Status assemblies can be relinquished to a remote panel, located up to several miles away, by placing the LOCAL/REMOTE switch in the REMOTE position. This is accomplished via a five-channel 1200 bps data link system. With the LOCAL/REMOTE switch in the LOCAL position, the ON/OFF and RESET switches, located on the front panel of the Local Control/Status assembly, are in control. In the REMOTE position, these switches have no affect as control is then transferred to the remote control panel via the data link.

The Remote Control/Status assembly is an independent unit with the only power input requirement being 120 VAC. Power supplies and data line receiver/drivers are self contained within the assembly. The following functional operations are provided via this assembly.

- a. The on/off status, the executive, maintenance and data link malfunctions status, and the control status (remote or local) for each individual subsystem (azimuth, elevation, DME) are provided. All of these functions are displayed on the system status display.
- b. On/off and reset controls are provided for each subsystem. Thus, these functions can be performed from one central point via switches grouped by subsystem on the front panel.
- c. Variable Auxiliary data in respect to the facility status and runway surface conditions are originated from this assembly. This data is inputted via two encoding switches located on the lower center of the front panel.
- d. The station identification code monitor allows the stations identification code (Morse code), being transmitted by the azimuth transmitter, to be monitored at the operators' discretion via an on/off switch and volume control provided on the front panel.
- e. Incorporated with the station identification code monitor is an aural alarm system. This alarm system overrides the Morse code monitor regardless of what status this monitor may be in at the time. Whenever one of the subsystems develops an executive error and goes off the "air," the aural alarm may be silenced only by clearing the fault or via the alarm off switch. When the alarm off switch is used, the alarm off lamp blinks as a visual warning that the alarm has been disabled.
- f. The status display lamps are tested via a front panel mounted double action switch. When this switch is placed in the opposite direction, it serves as the aural alarm test.
- g. A front panel mounted lamp dimmer control is provided for adjusting the brilliance of the status display lamps to a comfortable level relative to the room lighting conditions.

The first three functions make use of the facilities provided by the data link which communicates with the subsystems. In the case of the first two functions, this is accomplished on an interrogation and reply basis. The master interrogates each of the subsystems in sequence, then receives the replies and

updates itself. The variable Aux data is transmitted only. This data is sent to the AZ site where it is then transmitted.

The light driver/alarm provides the lamp drivers for operating the status display, circuits for the lamp and aural alarm test, lamp dimmer circuits, aural alarm sweep oscillator, Morse code monitor amplifier, and the visual alarm-off indicator.

The Remote Control/Status assembly also interfaces with the Remote Status assembly via a twenty-seven-pair cable and multipin connector.

Currently, the Remote Control/Status assembly is located in the AZ auxiliary cabinet in the AZ equipment shelter. In a normal operating environment, this assembly would be located in the ATC equipment room.

3.2.1.10.2 Remote Status - The Remote Status Assembly is an independent unit with the only power input requirement being 120 VAC. Power supply and data line receivers are self-contained within the assembly. The following functional operations are provided by this assembly:

- a. The on/off status, the executive, maintenance, and data link malfunction status (remote or local) for each individual subsystem (AZ, EL, DME) are provided. All of these functions are displayed on the system status display.
- b. The station identification code monitor allows the stations' identification code (Morse code), being transmitted by the azimuth transmitter, to be monitored at the operator's discretion via an on/off switch and volume controls provided on the front panel.
- c. Incorporated with the station identification code monitor is an aural alarm system. This alarm system overrides the Morse code monitor regardless of what status this monitor may be in at the time. Whenever one of the subsystems develops an executive error and goes off the "air," the aural alarm may be silenced only by clearing the fault or via the alarm off switch. When the alarm off switch is used, the alarm off lamp blinks as a visual warning that the aural alarm has been disabled.
- d. The status display lamps are tested via a front panel mounted double action switch. When this switch is placed in the opposite direction, it serves as the aural alarm test.

- e. A front panel mounted lamp dimmer control is provided for adjusting the brilliance of the STATUS DISPLAY lamps to a comfortable level relative to the room lighting conditions.

The Remote Status assembly contains the lamp and aural alarm test circuit, lamp dimmer circuits, aural alarm sweep oscillator, Morse code monitor amplifier, and the visual alarm indicator. The Remote Status assembly interfaces with the Remote Control/Status assembly via a 27-pair cable.

3.2.1.11 Distance Measuring Equipment - The distance measuring equipment (DME) used in the Basic Narrow system is an Aerocom model 5351A, modified by Bendix to meet the precision DME system requirement of the 100-foot (2σ) path following error. The ground transponder has a 2σ path following error of 65 feet, which is the RSS of ± 35 feet bias error, ± 30 feet noise error, and ± 45 feet multipath error, at the MGA of 50 feet and a range of 15,000 feet from the AZ antenna.

3.2.1.11.1 Modifications to Commercial System - Table 3-3 lists the unmodified and modified parameters of the DME. A block diagram of the ground transponder is shown in Figure 3-16. Circuits which were modified by Bendix are marked with an asterisk. A description of the modifications is given below.

a. Monitor	Modified to interface with AZ monitor and to monitor increased delay stability.
b. Control Circuit	A shutdown delay circuit added which is compatible with the new automatic delay stabilization.
c. Power Supply	A power supply added to provide +70 VDC for the new Bendix transmitters.
d. Signal Generator	The leading edge of the first interrogation pulse modified for a cosine wave shape. A new threshold detector installed.
e. Modulator	Redesigned for higher duty cycle.
f. Transmitter and Pre-driver	Aerocom transmitter replaced with Bendix Avionics Interrogator Model 2030 transmitter to improve linearity.

TABLE 3-3. L-BAND DME TRANSPONDER SPECIFICATION

PARAMETER	STANDARD UNMODIFIED	PRECISION MODIFIED
Transmitter Peak Power (Watts)	100	100
Sensitivity dBm	-87	-63
Receiver Bandwidth, kHz	350	3500
Threshold	-6 dB	0.1 μ s*
Range Accuracy(2 sigma), ft.	250 feet	65 feet
Adjacent Channel Rejection, dB	80	80
1st IF Frequency MHz (Log)	63	63
2nd IF Frequency MHz	10.7	10.7
Spurious Rejection, dB	75	75
Decoder Bandwidth, kHz	350	350
Time Delay Steps, sec	0.1	0.02
Wave Shape (1st Pulse)	Gaussian	\cos/\cos^2
Spurious Radiation, dBc	-60	-60
Delay Stability (Long Term)	$\pm 1.0 \mu$ s	$\pm 0.01 \mu$ s
Frequency, Receive MHz	1025 - 1150	1025-1150
Frequency, Transmit MHz	962 - 1213	962-1213

* Variable, delay and compare

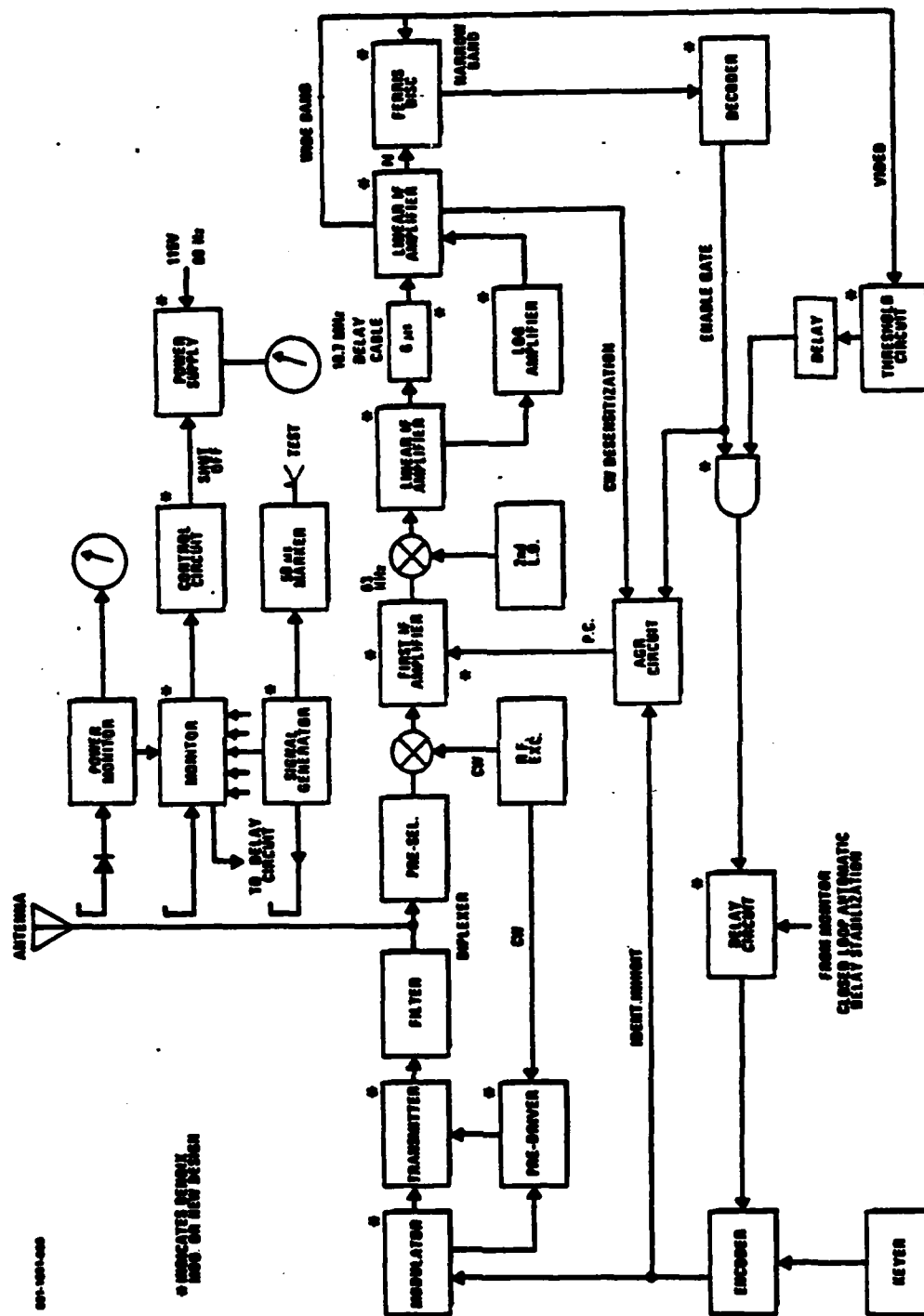


FIGURE 3-16. PRECISION L-BAND DME. TRANSPONDER BLOCK DIAGRAM

- g. Diplexer A 50 μ s delay calibration marker generator and an automatic delay stabilization circuit added.
- h. First IF Amplifier Redesigned to provide 3.5 MHz bandwidth. A lumped filter installed.
- i. Linear IF Amplifier Redesigned to achieve 3.5 MHz bandwidth. Voltage controlled delay multivibrator with charging circuit.
- j. Delay Cable 40 feet of delay cable added to improve the instantaneous AGC circuit.
- k. Ferris Discriminator New Discriminator added.
- l. LOG IF Amplifier Redesigned to improve performance over the dynamic range.
- m. Multivibrator and Delay Circuit New voltage controlled delay multivibrators with charging circuit added.
- n. Decoder New decoder added.
- o. Threshold Circuit New threshold circuit added.

3.2.1.11.2 System Operation - In the receive mode of operation, received signals from airborne interrogators are coupled from the DME transponder antenna to the diplexer and to the transponder receiver mixer. Also coupled to the mixer is the output of the receiver local oscillator from the RF exciter whose frequency is 63 MHz removed from the station assigned channel receive frequency. The mixer IF output, 63 MHz, is coupled through a coaxial cable to the First IF Amp. The First IF Amp provides amplification and second mixing of the received signals to a frequency of 10.7 MHz and provides two outputs. One of the 10.7 MHz outputs is coupled through a coaxial line to the Log Amp input. The other 10.7 MHz output is delayed by a 6 μ s passive delay line and coupled through a coaxial line to the input of the Linear IF Amp. The Log Amp amplifies and detects the signals and provides a tracking pulse AGC voltage signal to the Linear Amp so that the delayed signals from the First IF Amp coupled to the Linear Amp are linearly amplified and then detected by means of a Ferris type discriminator. The narrow

band output of the Ferris discriminator is coupled to the Decoder which checks the validity of the received pulses. If valid, the Decoder provides an enable output to an AND gate if the interrogation is on the correct channel. Interrogations from adjacent channels will not produce an enable gate by virtue of the dual mode Ferris discriminator and replies to such interrogations are, therefore, inhibited. The wideband output of the Ferris discriminator is used for accurate range timing and is coupled to the threshold circuits. The output of this circuit is coupled along with the enable gate to the AND circuit. A valid interrogation (correct pulse pair spacing and frequency) produces an output pulse from the AND circuit. This pulse is delayed by a voltage controlled Delay Circuit which is part of the automatic delay stabilization loop. Approximately 42 μ s later, the Encoder is triggered and generates a reply pulse pair with the appropriate pulse pair spacing. The AGR module counts the number of interrogations received by the transponder and reduces the gain of the First IF Amp when the interrogations exceed a rate of 2700 to maintain the maximum interrogation rate of 2700. The gain is also reduced during CW interference.

The IC Keyer generates Morse code station identification signals every 30 seconds. During the identification period, the First IF Amp is inhibited by the AGR circuit to prevent interference from normal interrogations.

In the transmit mode of operation, after the transponder has received an acceptable pulse pair from an interrogator, it produces a trigger signal for the transponder Encoder and a properly encoded pulse pair is transmitted. The Decoder output trigger causes the Encoder to generate a pair of pulses, properly spaced, to modulate the transmitter. The Encoder provides a gate signal to the modulator. The modulator, in turn, provides a gate signal to the RF Pre-Driver and a modulating oscillator, operating at 1/12 the transmitter output frequency. The oscillator signal frequency is multiplied by 12 prior to use in the RF Pre-Driver and the local oscillator. The RF Pre-Driver receives approximately 3 mW of RF power at the transmit frequency from the Exciter and, after amplification, provides a 0.5 watt peak power input at the transmit frequency to the Power Amp. The Power Amp further amplifies the RF and, in conjunction with the modulating pulses from the modulator, produces RF output pulses of 100 watts (minimum) peak power. The Power Amp output is connected to the diplexer through a ferrite circulator and the diplexer output is supplied to the antenna. Couplers in the coaxial transmission line between the diplexer and the antenna provide for coupling to the Signal Generator and for measurement of the forward and reflected peak output power. The power output is adjusted (final installation with antenna) to the level which is compatible with the ICAO spectrum splatter requirements.

The monitor functions are accomplished by the Monitor unit, the Signal Generator unit, and the Control unit. The Signal Generator provides internal interrogation signals at a nominal rate of 96 pulse pair interrogations per second. The interrogation signals are coupled to the DME receiver and the DME transmitter output is coupled to a detector which provides detected pulse signals to the Monitor unit where the pulse amplitude is evaluated for power output performance and for fault status information on monitored parameters other than power output, including station identification, PRF, reply delay, and reply efficiency.

A reply delay fault is recognized as an executive fault and causes shutdown of the transponder. All of the other monitored parameters are normally considered as secondary parameters. A fault condition in any secondary parameter results only in a maintenance fault. Provision is made to wire only one or more of the secondary parameter fault circuits so that they are treated as executive faults if so desired.

The internal transponder delay is directly and critically related to the overall system distance measuring accuracy, and must therefore, be tightly controlled and monitored. In the Bendix modified MLS DME transponder, the delay is automatically controlled by a closed loop circuit. This circuit works in conjunction with the built-in signal generator, which continuously interrogates (approximately 96 times per second) the transponder and causes it to reply. The inherent time delay through the transponder is compared with a crystal controlled 50 μ s reference. Any deviations from this reference are detected and are automatically and continuously corrected. The delay is adjustable over a small range.

The Control unit provides for the control functions and the display of the operational status. Fault status signals from the Monitor unit are received by the Control unit which provides corresponding fault alarm and/or shutdown. The Control unit provides a front panel display of executive and maintenance fault status of the transponder. A front panel display is also provided showing individually the fault status of each monitored parameter for the transponder.

3.2.1.11.3 Antenna - The DME antenna is a Chu Associates Model CA-3117 broadband unidirectional array consisting of two broadband colinear radiators and a reflector. The assembly is enclosed in a high-strength fiberglass radome.

The vertically polarized radiators provide more than 9-1/2 dBi gain over the 960-1215 MHz frequency band. Input VSWR is less than 1.5 at all frequencies. A 5 degree \pm 1 degree

upward beam tilt is provided to reduce ground reflections. Gapless vertical coverage to a level 20 dB below the peak of the main beam is provided to elevation angles of 45 degrees at frequencies below 1100 MHz and elevation angle of 35 degrees at higher frequencies. Essentially, gapless coverage to 90 degrees is provided at a level 30 dB below the peak of the main beam.

RF connection is made to a Type C connector recessed in the base. Two Type N connectors, also recessed in the base, provide access to RF monitor probes.

A 1-inch pipe extends through the antenna for installation and connection to dual aircraft obstruction lights atop the antenna.

The base-mounted assembly is a "O"-ring sealed unit capable of being pressurized to 15 psig. The radome is easily removed for access to the radiator assembly.

The electrical and mechanical characteristics are summarized below.

Frequency	960-1215 MHz
Gain	≥ 9.5 dBi
Number of Elements	2
Power Handling Capability	3 kW peak
VSWR	$\leq 1.5:1$
Impedance	50 ohms
Polarization	Vertical
Horizontal Beamwidth	$\geq 70^\circ$
Vertical Pattern	
Beamwidth	$\geq 28^\circ$
Tilt	$\pm 5^\circ \pm 1^\circ$ above horizon
Gain at 0° elevation	≥ 6 dBi
Input Connector	Type C female
Monitor Probes	
Coupling	-25 \pm 5 dB
Connector	Type N female
Height	31 inches
Diameter	8.75 inches
Weight	26 pounds

Patterns of the antenna are shown in Figures 3-17 and 3-18. Both patterns are at 1100 MHz. The azimuth pattern is at 5 degrees elevation and the elevation pattern is at 0 degrees azimuth. The half-power beamwidths are approximately 80.5 degrees in azimuth and 30.3 degrees in elevation. The elevation beam is tilted upward 4.9 degrees.

3.2.1.12 Antenna Case - Major components in the AZ antenna enclosure are shown in Figure 3-3. The enclosure contains the scanning lens antenna and its scan switch matrix, the Beam Steering Unit, the Fine Scan Modulator, Power Supplies, Radome Deicing equipment, and an Environmental Control System. The antenna case is a waterproof metal structure measuring 96 inches wide, 64 inches high, 24 inches deep and with the housed equipment weighs approximately 1200 pounds. To protect the antenna aperture, the front of the antenna case is fitted with a sandwich type radome made of fiberglass reinforced polyester. This material consists of two fiberglass reinforced skins over a honeycomb core. The sandwich is approximately 0.58 inches thick.

An access cover is provided on one side of the antenna case to permit servicing. The access cover is held in place by several quick-release fasteners so that removal or replacement of a cover can be accomplished in seconds. Support poles on the case provide mechanical adjustment for alignment and also for positioning the case a minimum of 3 feet off local ground for snow clearance.

The Environmental Control System consists of air conditioning, heating, exhaust blower motor, thermostats, and a humidistat. A ventilation system consisting of an exhaust blower and adjustable louvers serves as a back-up in the event of an air conditioning failure. The antenna enclosure temperature is continually sensed and fed to the monitor system as a maintenance monitor point.

A heated-wire concept is used for radome deicing by placing a pattern of horizontal wires for resistance heating in the plastic radome. These closely spaced wires are heated directly with line power. The deicing control for all radome heaters is located in the equipment shelter.

With the exception of the RF energy, all of the antenna enclosure interfacing signals are made via a buried cable containing shielded, twisted pair, no. 19 gauge wire. Lightning protection is provided at both ends of all cables. The RF interconnection between the transmitter, located in the equipment shelter and the AZ antenna enclosure, is made via buried elliptical waveguide to minimize RF loss. A waveguide pressurization unit insures the integrity of this RF transmission line. For the elevation subsystem, 7/8 semirigid coaxial line is

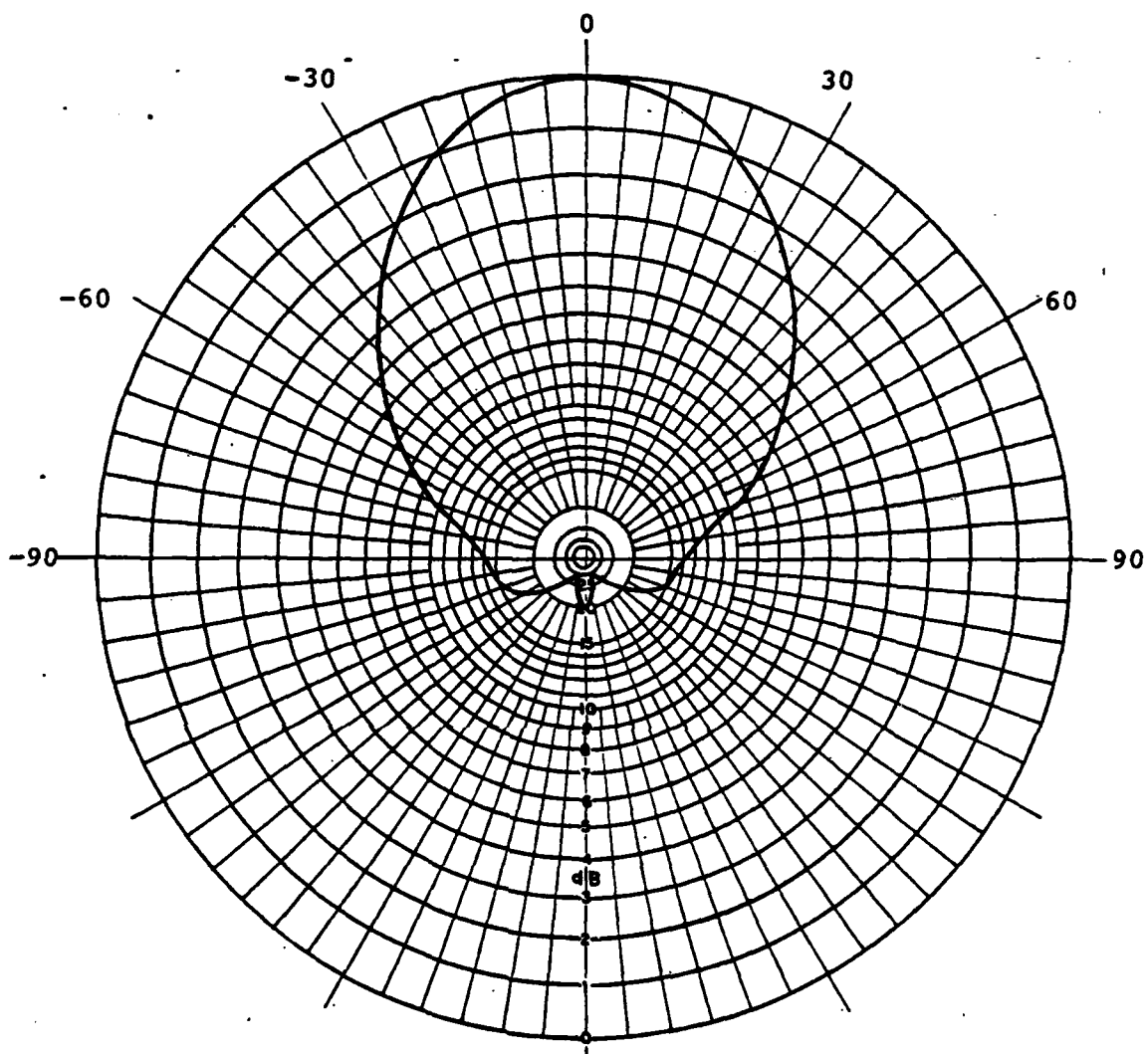


FIGURE 3-17. DME ANTENNA AZIMUTH PATTERN, 1100 MHz

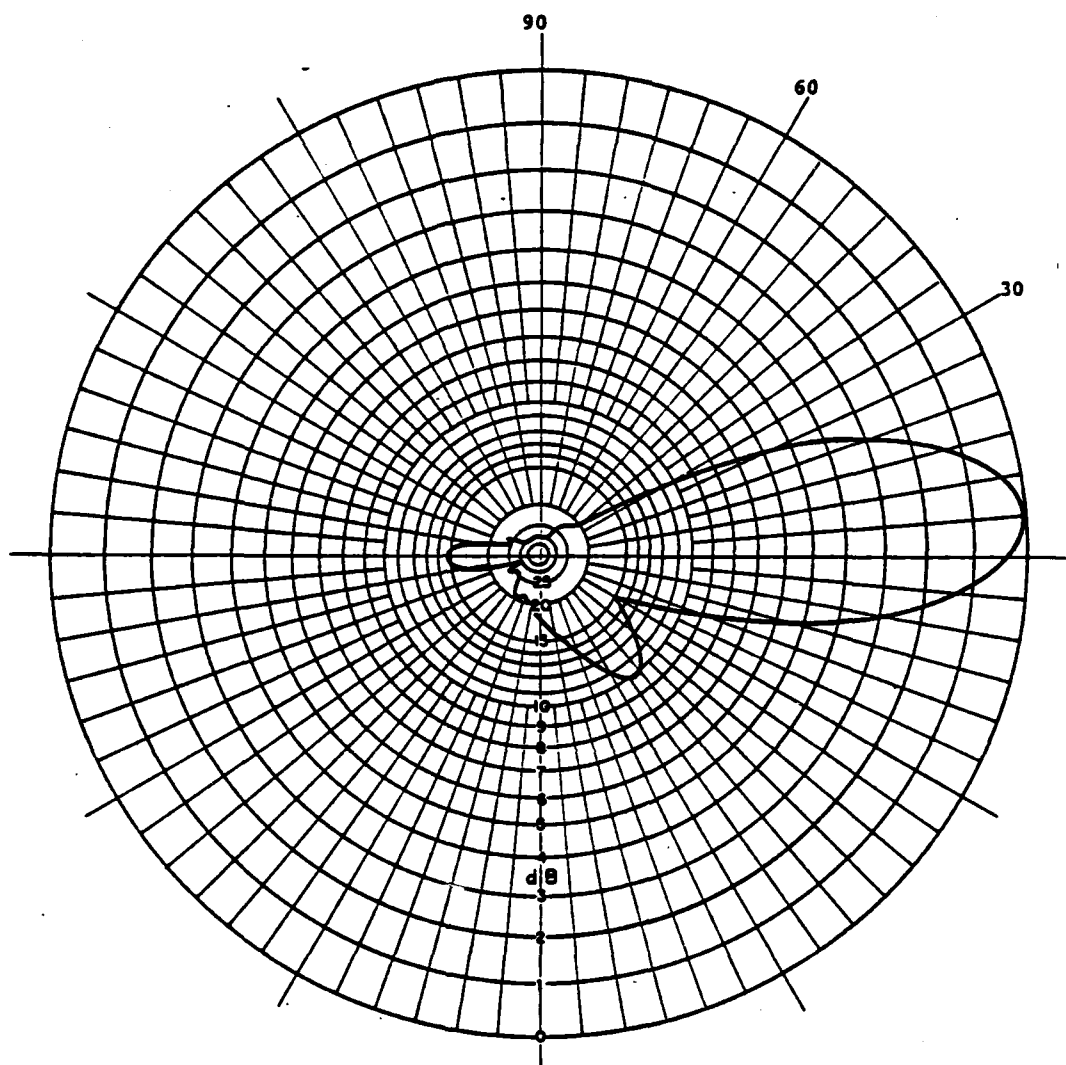


FIGURE 3-18. DME ANTENNA ELEVATION PATTERN,
1100 MHz

employed as the RF transmission line between the equipment shelter and antenna enclosure.

The case is designed to meet frangibility specifications, and the frangibility design is shown in Figure 3-19. Structural rigidity of the support is maintained so that the pointing accuracy of the antenna is not affected.

3.2.1.13 Electronics Shelter - The electronics shelter is shown in Figure 2-8. A plan view of the interior of the shelter is shown in Figure 3-20. This shelter houses three cabinets of equipment; (1) the Angle Electronics Cabinet which contains the TWT Amplifier, RF Unit, Local Control/Status, Maintenance Monitor, and Antenna Select Switch, (2) the Auxiliary Cabinet which contains the Remote Control/Status and Maintenance Display, and (3) the DME Cabinet. In addition, the shelter has a power distribution box, signal distribution box, auxiliary power box, work bench, storage cabinet, fire extinguisher, and waveguide pressurization unit. Mounted external to the shelter are the Forward Ident, the left and right SLS, and the DME antennas. The shelter is positioned on a concrete slab, and its exterior is weatherproof.

An Environmental Control System is provided in the shelter consisting of an air conditioner/heater, a ventilator system, and associated control circuits. The air conditioner/heater is a standard home air conditioner containing an electrical heating element and modified to permit operation in cold outside temperatures, an automatic evaporator deicer, and an automatic changeover thermostat. The unit will automatically change over between cooling and heating operation as controlled by the thermostat. The thermostat is normally set for a shelter temperature of 75°F (24°C). The ventilator system provides emergency cooling in the event of air conditioner failure. If the shelter temperature rises above 95°F (35°C), intake louvers on the rear wall open, and the exhaust fan turns on, pulling outside air through the shelter, and primary power is disconnected from the air conditioner. Environmental control circuits provide a 3- to 4-minute time delay following primary power turn-on before applying primary power to the air conditioner/heater. This time delay prevents the air conditioner from tripping its circuit breaker after short power interruptions. The environmental control circuits also control the ventilator system and provide means to manually bypass the ventilator system and operate the air conditioner when the shelter temperature is above 95°F. An outside thermostat and humidity sensor are used to control the antenna radome deice heaters. The thermostat and humidity sensor are located in a ventilated metal box on the outside end wall of the electronics shelter. Power is applied to the radome heaters when the outside temperature is below 40°F (4°C) and the humidity is greater than 80 percent.

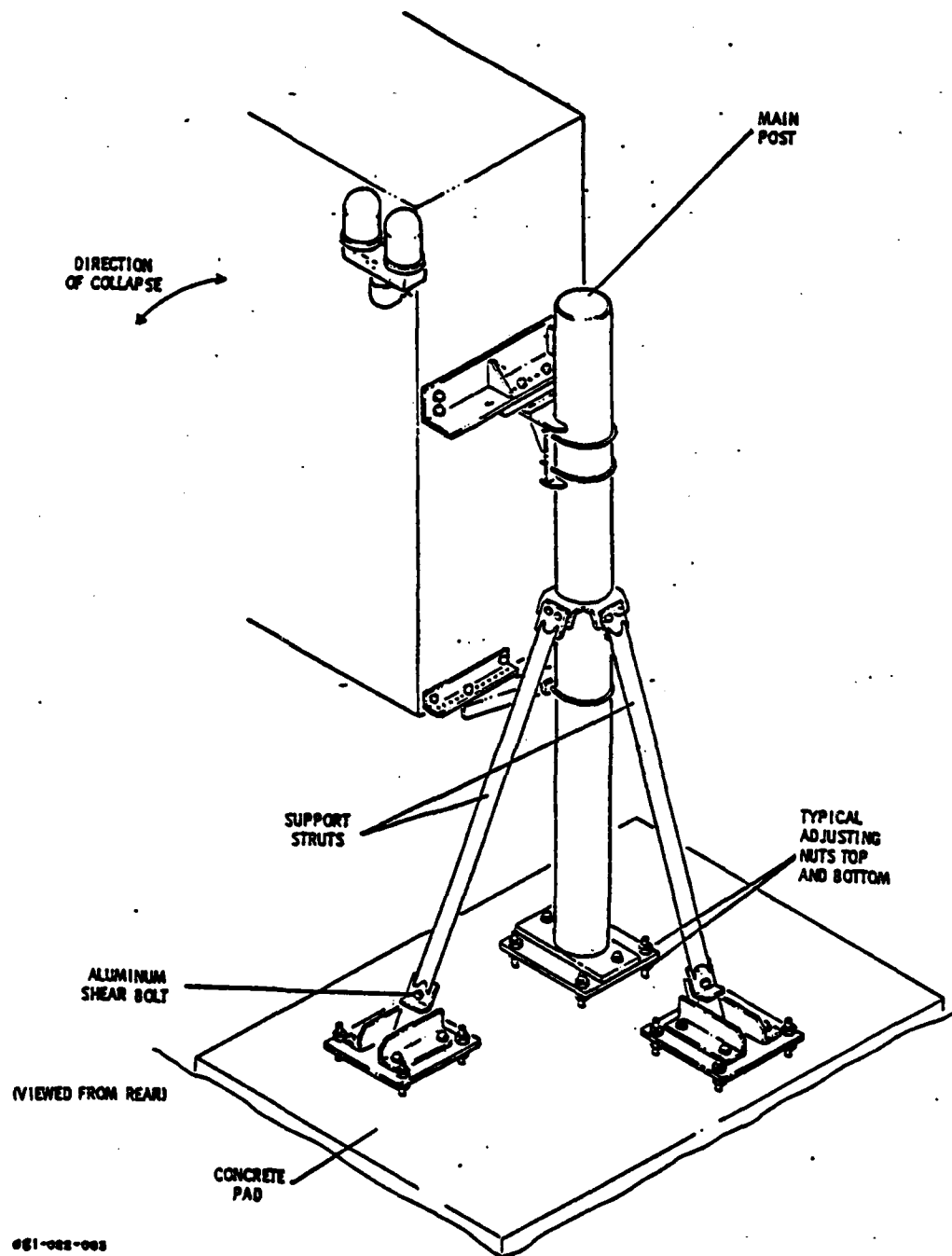


FIGURE 3-19. AZ ANTENNA CASE, FRANGIBILITY DESIGN

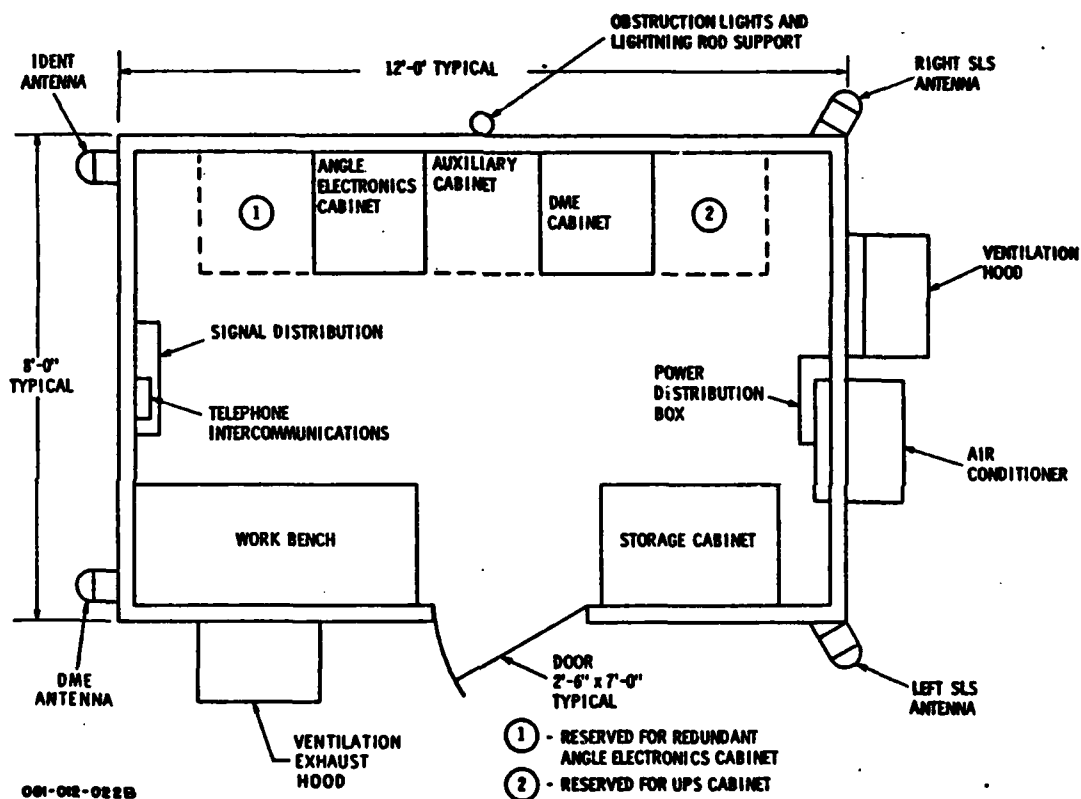


FIGURE 3-20. AZIMUTH EQUIPMENT SHELTER, PLAN VIEW

3.2.2 Elevation Equipment

3.2.2.1 Scanning Array

3.2.2.1.1 Description - The components comprising the EL scan array are shown in Figure 3-21. General theory of operation of the array is very similar to that of the AZ scan array (paragraph 3.2.1.1.1), but the quantities of components used is different. Since the EL array provides proportional guidance only over a 15 degree sector, the number of lens inputs is reduced to 16, and this reduces the number of RF switches required to four. The EL beam is stepped in the same manner as the AZ beam.

A view of the EL antenna is shown in Figure 3-22. The radiating aperture is a vertical array of coaxial dipoles backed by a shaped reflector. Nominal characteristics of the EL array are listed below.

Beamwidth	1.5 degree
Side Lobes	≤ -20 dB
No. Elements	64 active + 2 parasitic
Spacing	$0.72 \lambda_0$
Start Angle	17.587 degrees
Stop Angle	0 degree
Fine Scan Steps	141
Gain (at FSM input)	20.4 dBi
Guidance Coverage	1 degree to 15 degrees

3.2.2.1.2 Rotman Lens - The lens used in the EL array is identical to that used in the AZ array. As mentioned previously, the number of lens inputs has been reduced to 16 (see Figure 3-23) since a sector coverage of less than 20 degrees is required. The number of outputs is 64, the same as the AZ array, but the increased inter-element spacing of 0.72λ permits the 1.5 degree beamwidth to be obtained. This spacing is still small enough to preclude the appearance of grating lobes at any scan angle in coverage over the frequency band.

The practice of increasing (decreasing) the radiating element spacing while maintaining a constant lens geometry is referred to as minification (magnification). It has two noticeable effects. First, the beamwidth will be narrowed (broadened) as with any linear aperture. Second, the beam will be displaced less (more) from boresight when a given set of inputs is excited. This means that, as the radiating element spacing is increased,

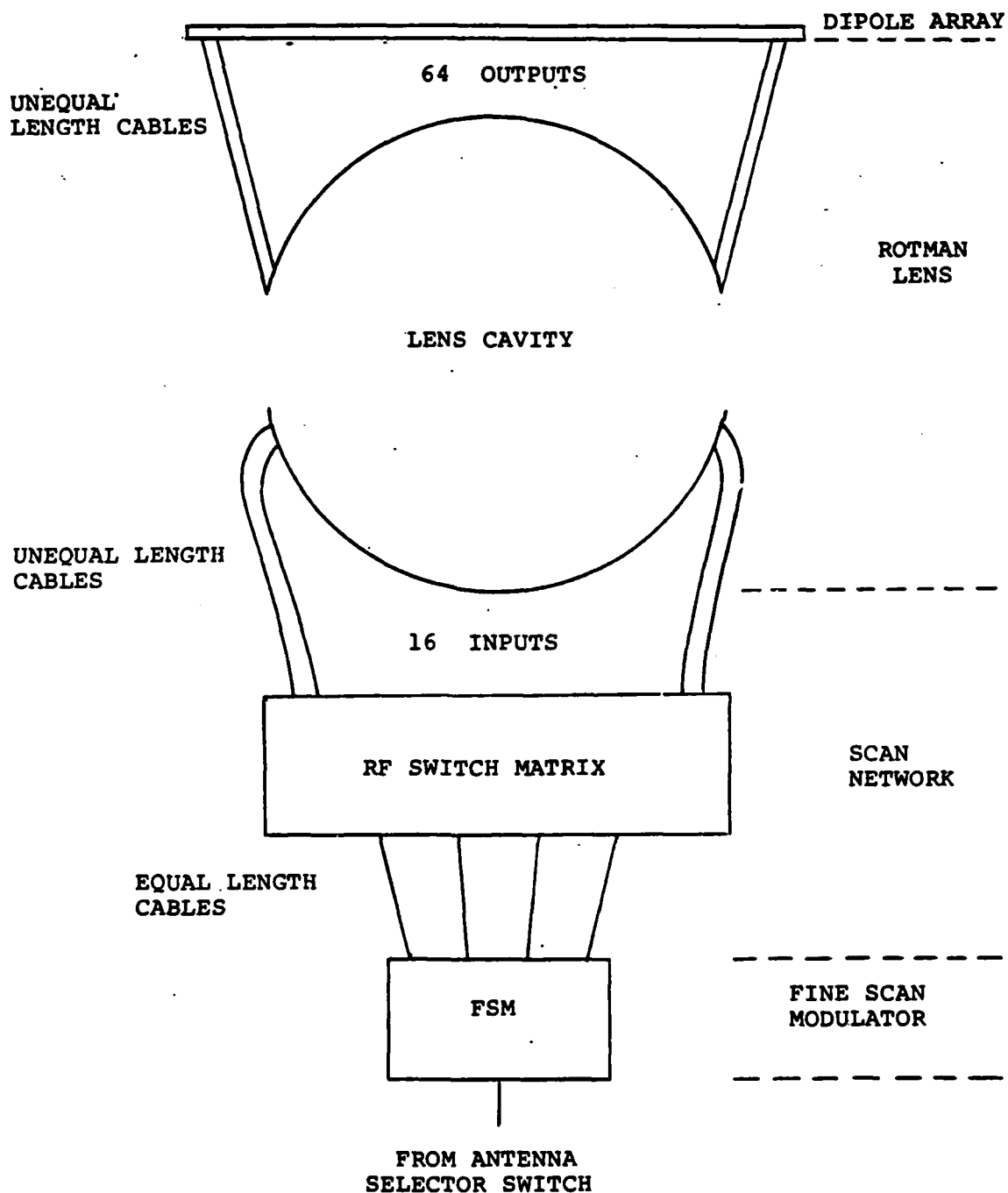


FIGURE 3-21. BN EL SCANNING ARRAY

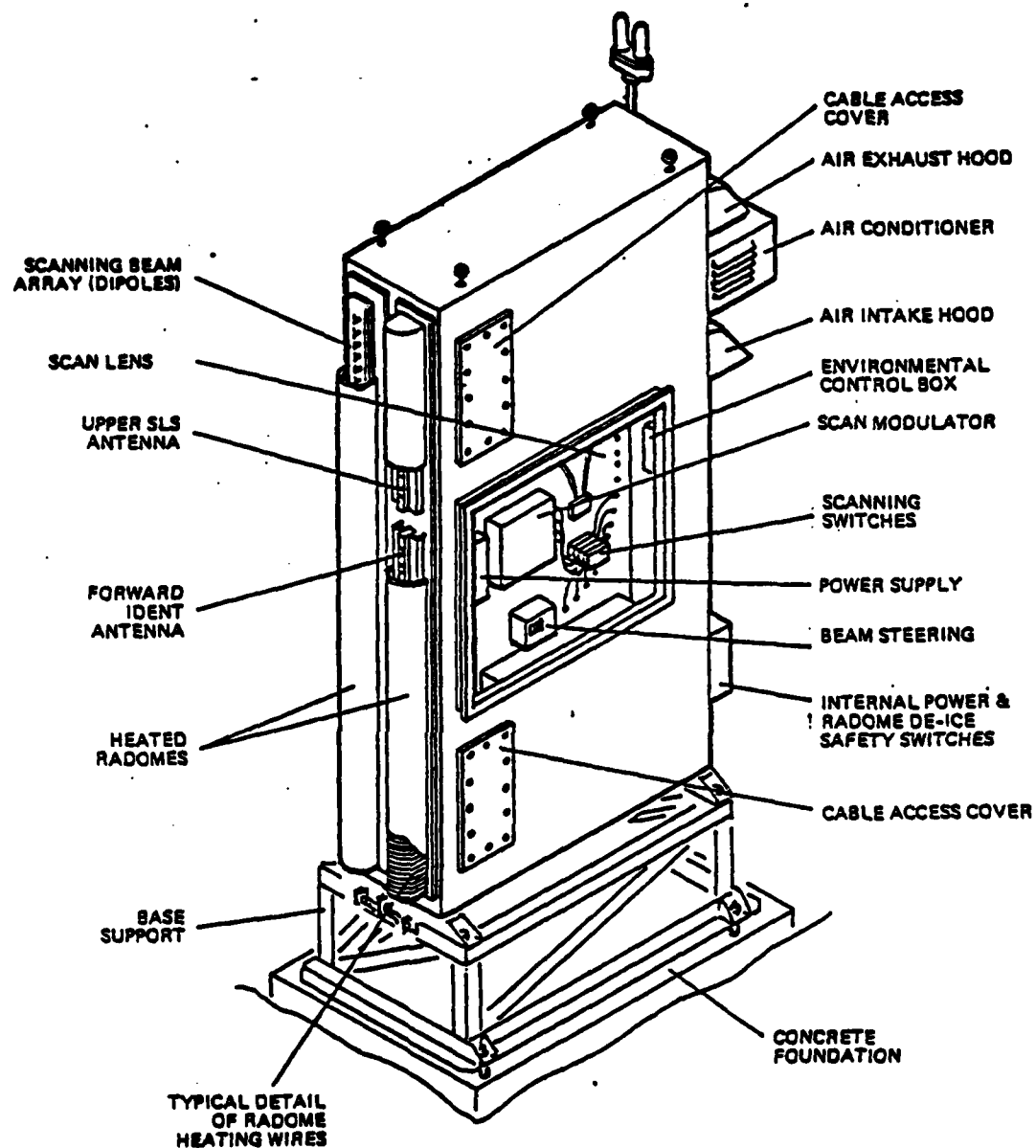


FIGURE 3-22. BN EL ANTENNA MAJOR COMPONENTS

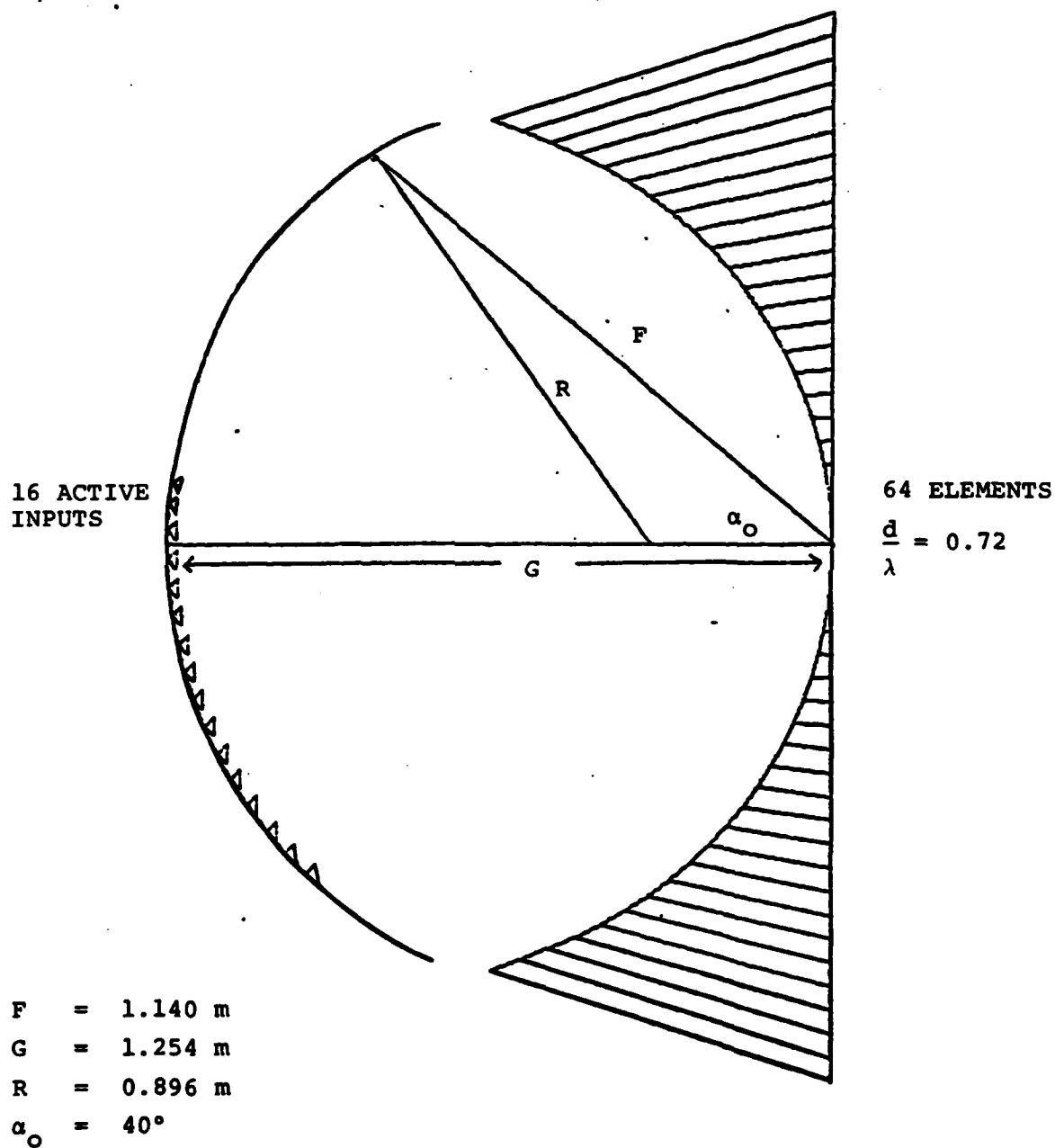


FIGURE 3-23. BN EL ROTMAN LENS

a larger portion of the lens focal arc will have to be used to maintain a constant coverage. This will require, at most, an additional RF switch and some cables, but this is a small cost relative to that involved in the logistics of maintaining two lens designs instead of one. The orthogonality of the radiated beams is not disturbed by the minification.

Figure 3-24 is a composite plot of every 5th beam from numbers 1 through 141.

3.2.2.1.3 Scan Network - A block diagram of the elevation scan network is shown in Figure 3-25. This is similar in concept to the azimuth scan network (paragraph 3.2.1.1.3), the only difference being that the second tier of 12 switches in the AZ scan network has been deleted. The unequal length cables are still required to maintain phase equality of the orthogonal beams.

The switches are identical to those used in the AZ scan network and described in paragraph 3.2.1.1.3.

3.2.2.1.4 Fine Scan Modulator - The EL fine scan modulator is identical to that used in the AZ array. See paragraph 3.2.1.1.4 for details of theory and performance.

3.2.2.1.5 Dipole Array - The radiating aperture consists of 64 coaxial dipoles, spaced 0.72λ , with a shaped ground plane to provide the desired horizontal coverage. The azimuth pattern of a single dipole is shown in Figure 3-26. Pattern fall-off is 3 dB at ± 20 degrees and approximately 7 dB at ± 40 degrees azimuth.

3.2.2.2 Forward Ident Antenna - This antenna is identical to the BN AZ forward ident antenna described in paragraph 3.1.1.2.

3.2.2.3 Upper SLS Antenna - The upper SLS antenna is a slotted waveguide element similar to the forward ident antenna, but with a smaller (2 ft vs. 4 ft) aperture. The vertical pattern of this antenna is shown in Figure 3-27.

3.2.2.4 Antenna Selector Switch - The antenna selector switch is a modular SP3T switch that is identical, except for the number of outputs, to the BN AZ antenna selector switch described in paragraph 3.2.1.4.

3.2.2.5 Beam Steering - This Beam Steering Electronics Subassembly provides control signals to the scan switches and scan modulator which steer the antenna beam in the required elevation TO-FRO sequence. This subassembly is mounted on the backside of the Rotman lens. A schematic of the Beam Steering equipment is shown in Figure 3-28. Functionally, this equipment can be divided into two sections, control and monitor. The control section develops the signals which actually control the beam scan, while the monitor section develops duplicate on-line signals and compares the two sets of signals to ensure that proper steering control is being achieved.

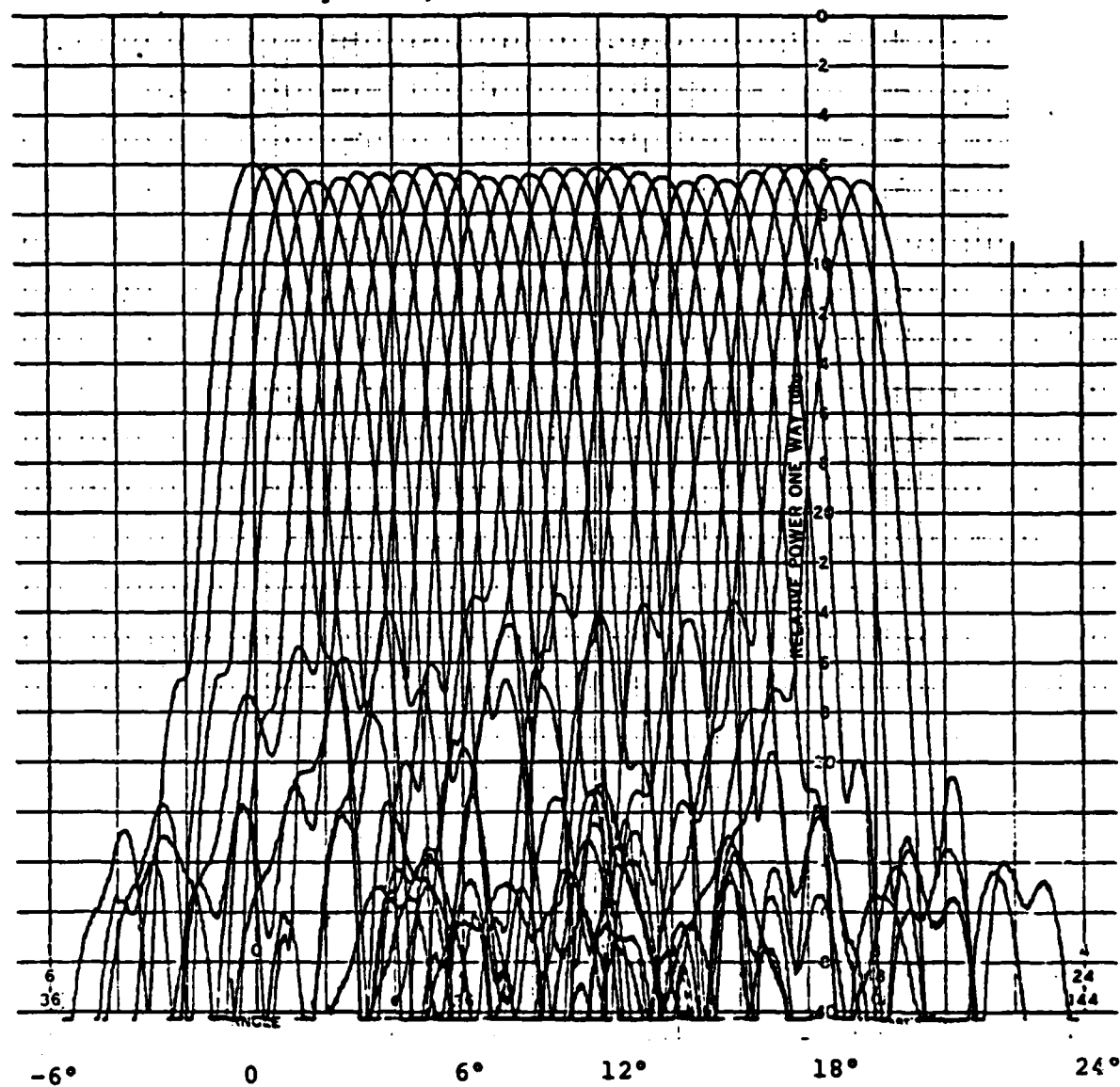


FIGURE 3-24. BASIC NARROW EL ELEVATION PATTERNS,
EVERY 5TH BEAM

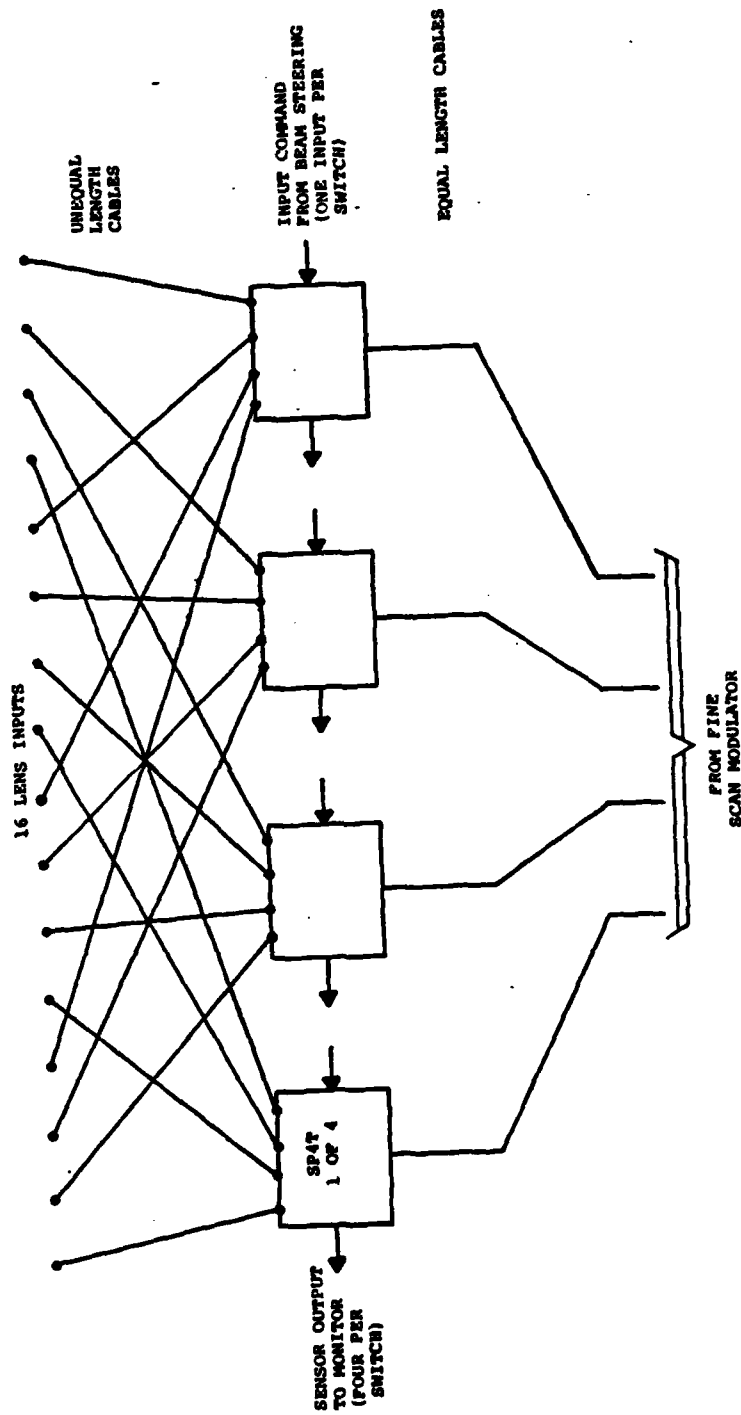


FIGURE 3-25. BASIC NARROW ELEVATION SCAN NETWORK

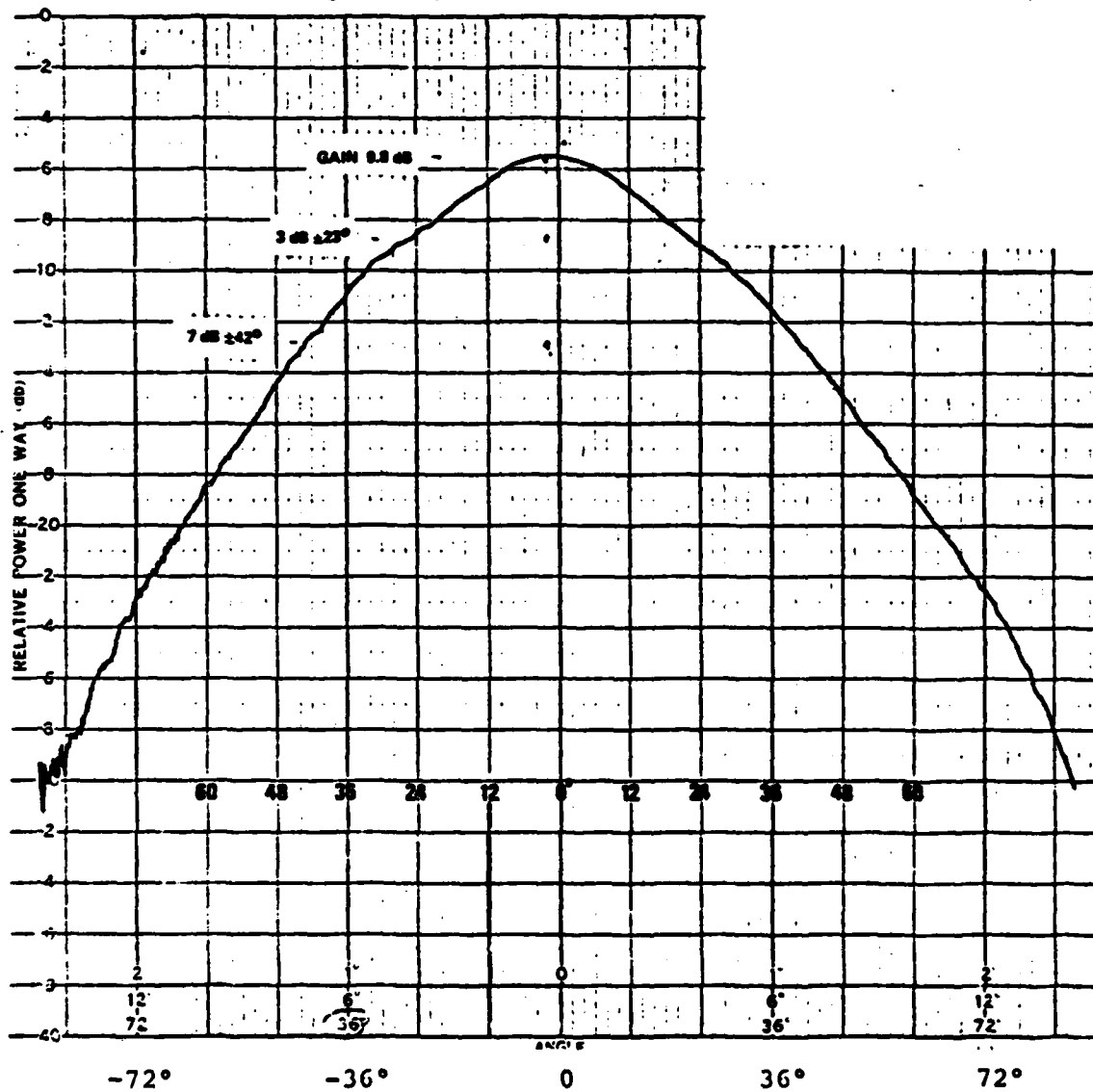


FIGURE 3-26. AZIMUTH PATTERN OF EL ANTENNAS FOR:
BASIC NARROW
SMALL COMMUNITY

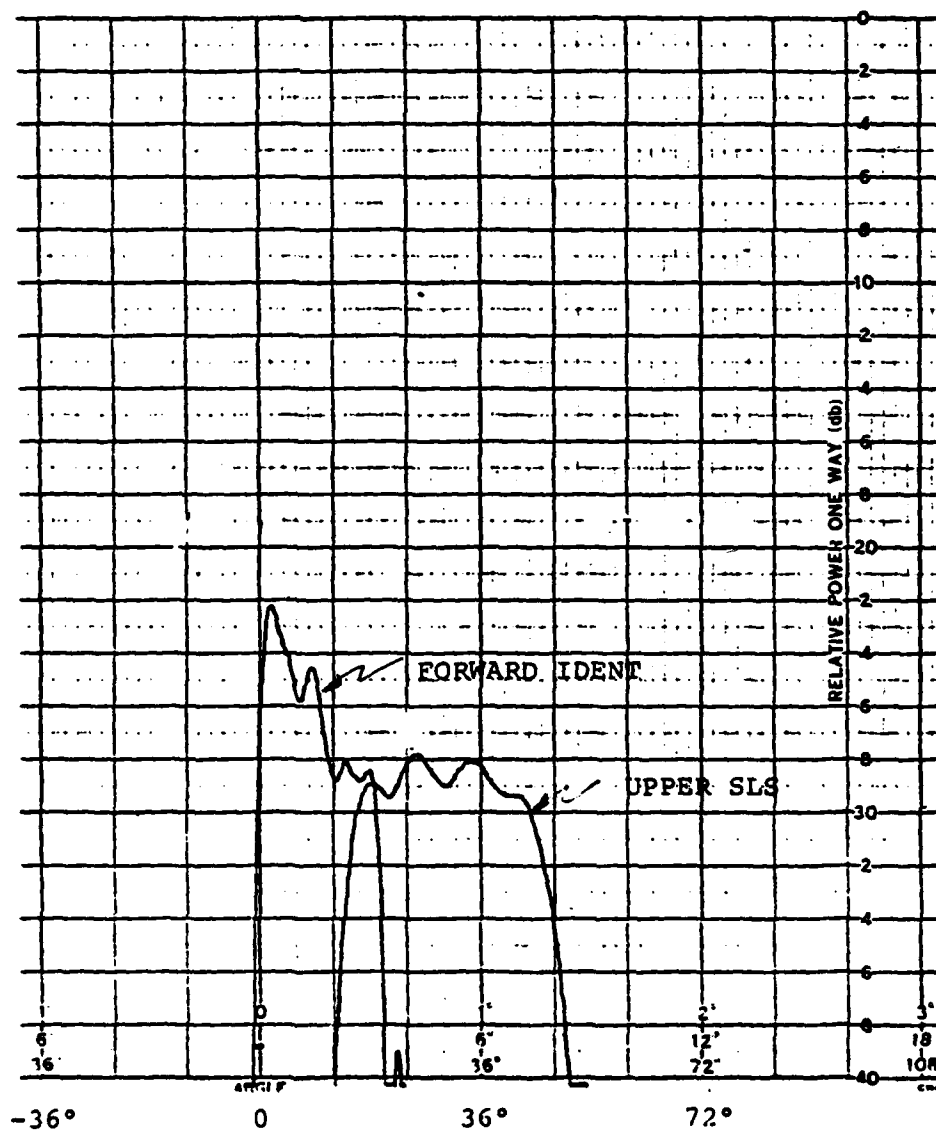


FIGURE 3-27. ELEVATION PATTERNS OF IDENT AND UPPER SLS ANTENNAS FOR:
BASIC NARROW
SMALL COMMUNITY

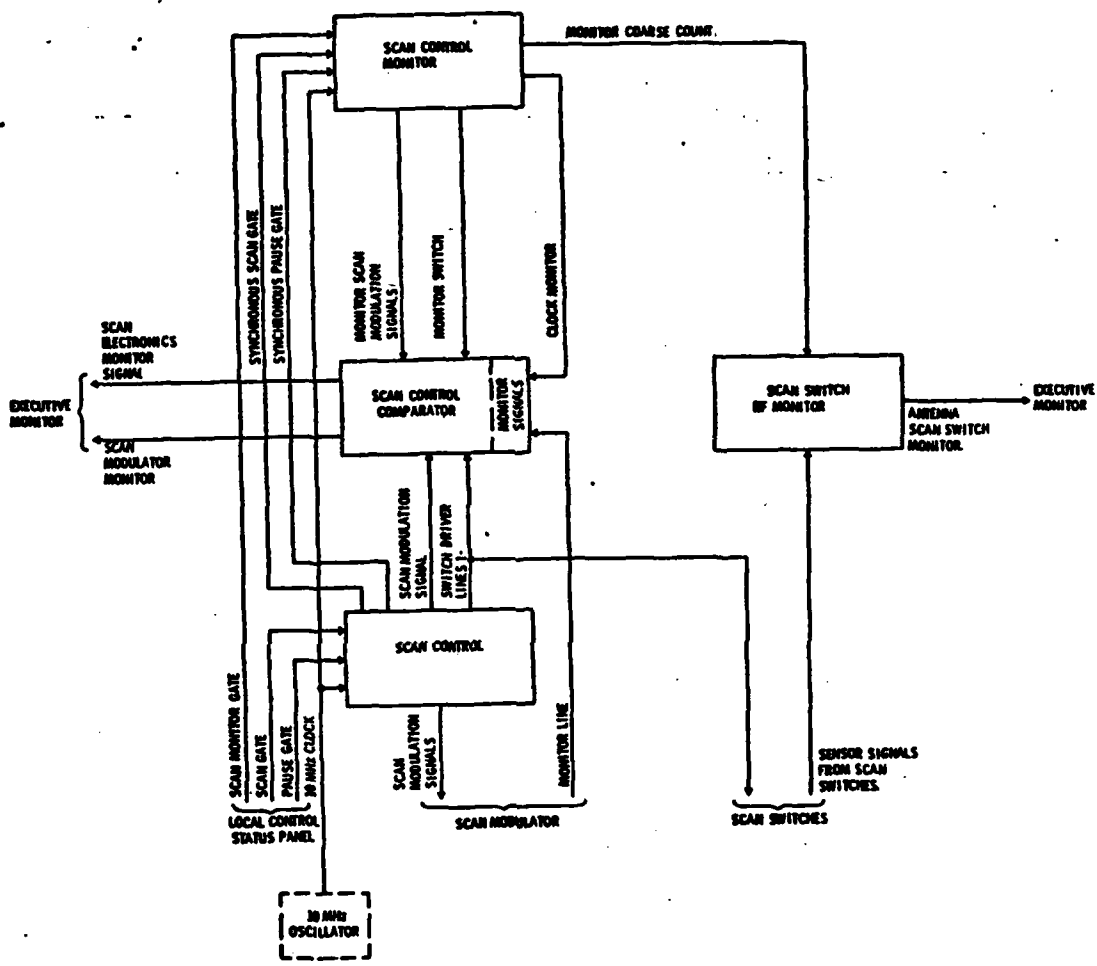


FIGURE 3-28. ELEVATION BEAM STEERING BLOCK DIAGRAM

3.2.2.5.1 Control Section - The control section utilizes the scan control only. Functionally, this section operates in the same manner as the AZ control section (see paragraph 3.2.1.5.1). There are, however, only 16 instead of 48 lens feeds which are energized. Thus, four instead of 16 scan switches are utilized. This eliminates the need for the Scan Switch Driver and the Intermediate Scan Switch Driver since the four scan switches are driven directly from the scan control.

3.2.2.5.2 Monitor Section - The monitor section utilizes the scan control monitor, scan control comparator, and the scan switch RF monitor. Functionally, this section operates in the same manner as the AZ monitor section (see paragraph 3.2.1.5.2). However, since there are four instead of 16 scan switches being utilized, there is no need for the scan switch RF monitor or the Intermediate scan switch RF monitor.

3.2.2.6 TWT Amplifier - The TWT amplifier for the EL system is identical to the AZ system TWT amplifier described in paragraph 3.2.1.6.

3.2.2.7 RF Unit - The EL system RF unit is identical to the AZ system RF unit described in paragraph 3.2.1.7.

3.2.2.8 Local Control/Status - The EL system Local Control/Status equipment is described in paragraph 3.2.1.8.

3.2.2.9 Monitor - The monitor system for the EL subsystem was described in paragraph 3.2.1.9 with the AZ subsystem monitoring.

3.2.2.10 Antenna Case - A cut-away view of the EL antenna enclosure was shown in Figure 3-22. This case contains the scanning lens antenna, the forward ident antenna, the upper SLS antenna, the scan switch matrix, the fine scan modulator, the beam steering unit, the antenna select switch, radome deicing equipment, and an environmental control system that is identical to that in the AZ antenna case.

The antenna case is a waterproof metal structure measuring 117 inches high, 57 inches (plus 5 inches for radome) deep, 24 inches wide and with the housed equipment weighs approximately 2000 pounds. The forward ident and the upper SLS antennas are mounted to the case adjacent to the scanning beam aperture. To protect the antennas, the front of the antenna case is fitted with two cylindrical thin-wall type radomes made of fiberglass reinforced polyester. One radome protects the scanning beam antenna aperture while the second radome protects the forward ident and the upper SLS antennas. Deicing is provided with dissipative wire grids embedded in the radomes. Access covers are provided on one side of the case to permit servicing. The access

covers are held in place by several quick-release fasteners so that removal or replacement of a cover can be accomplished in seconds. A pedestal support base provides mechanical adjustment for alignment, and also for positioning the case a minimum of 3 feet off local ground for snow clearance.

3.2.2.11 Electronics Shelter - The shelter for the EL subsystem is identical to that for the AZ subsystem described in paragraph 3.2.1.13. A plan view of the shelter is shown in Figure 3-29. The shelter contains two cabinets, the angle electronics cabinet and the auxiliary cabinet. The remainder of the interior is identical to the AZ shelter. No antennas are mounted on the outside of the shelter.

3.2.3 Applicable Documents

The intent of paragraph 3.2 has been to describe the BN equipment from the standpoint of system, subsystem, and major equipment descriptions. Detailed descriptions and operating procedures are contained in the following publications:

<u>TITLE</u>	<u>PUBLICATION NO.</u>
Microwave Landing System, Ground Subsystem, Basic Narrow Ground Equipment	TI 6850.32
Microwave Landing System, Ground Electronics, Basic Narrow Ground Equipment	TI 6850.33
Microwave Landing System, Maintenance Monitor Display, Basic Narrow Ground Equipment	TI 6850.31
Microwave Landing System, Vendor Data, Supplement, Basic Narrow Ground Equipment	TM 081-072
Microwave Landing System PC Card Test Procedures, Supplement, Basic Narrow Ground Equipment	TM 081-082
Microwave Landing System, Wire Lists, Supplement, Basic Narrow Ground Equipment	TM 081-083

3.3 SMALL COMMUNITY GROUND SUBSYSTEM

The SC Ground Subsystem description is presented in two parts, one for the AZ equipment and the other for the EL equipment. The major components listed in paragraph 2.4.1 for each

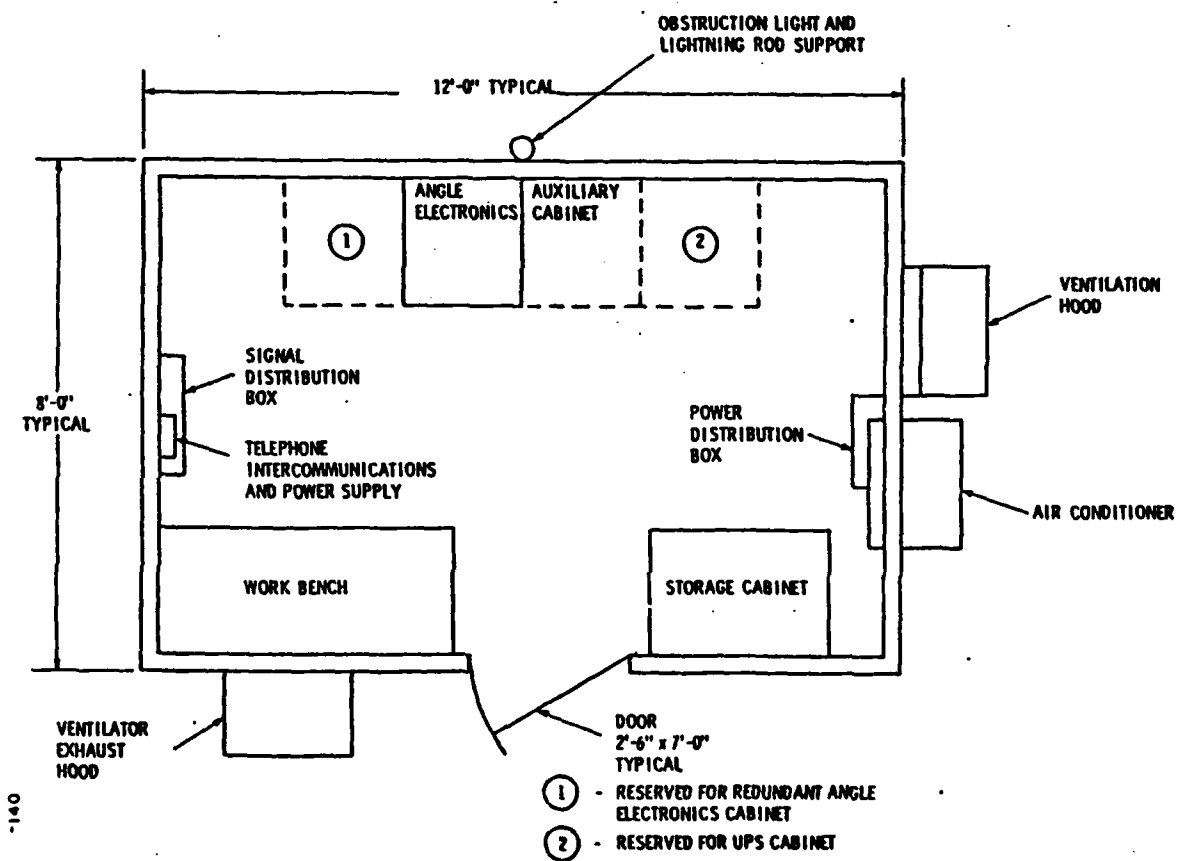


FIGURE 3-29. ELEVATION EQUIPMENT SHELTER, PLAN VIEW

equipment are discussed in detail. In addition, the antenna cases, with their environmental controls and ancillary equipment such as warning lights, lightning protection, power distribution, etc., are included.

3.3.1 Azimuth Equipment

3.3.1.1 Scanning Array

3.3.1.1.1 Description - The components comprising the AZ scan array are shown in Figure 3-30. The theory of operation is identical to that described previously (paragraph 3.2.1.1.1) for the BN AZ antenna. Front and rear views of the SC AZ antenna enclosure is shown in Figures 3-31 and 3-32. The nominal characteristics of the antenna are given below.

Beamwidth	3°
Sidelobes	≤ -20 dB
No. Elements	46 active + 2 parasitic
Spacing	$0.5\lambda_0$
Start Angle	12.462°
Stop Angle	-12.462°
Fine Scan Steps	101
Gain (at FSM input)	23.3 dBi
Guidance Coverage	±10°

3.3.1.1.2 Rotman Lens - A schematic of the Rotman lens is shown in Figure 3-33. The construction of the lens is similar to that of the BN lenses, but different design parameters have been used as indicated on the figure. It can be noted that the off-axis foci are at $\alpha_0 = \pm 40$ degrees. Ordinarily, this would not be the case when a lens had to scan only ± 10 degrees, but the 40 degrees design was used to increase commonality in the MLS system. The lens design shown in Figure 3-33 is also used for the SC EL antenna and may be used for a back azimuth antenna design. The lens feeds a 46-element slotted waveguide array, the design of the slotted waveguide elements being identical to that for the BN AZ antenna. The waveguide elements are spaced $0.5\lambda_0$.

Figure 3-34 is a composite showing every tenth beam in the step scan sequence.

3.3.1.1.3 Scan Network - A schematic of the scan network is shown in Figure 3-35. The RF switches are identical to those of the BN AZ described in paragraph 3.2.1.1.3.

3.3.1.1.4 Fine Scan Modulator - The fine scan modulator is identical to that of the BN AZ described in paragraph 3.2.1.1.4.

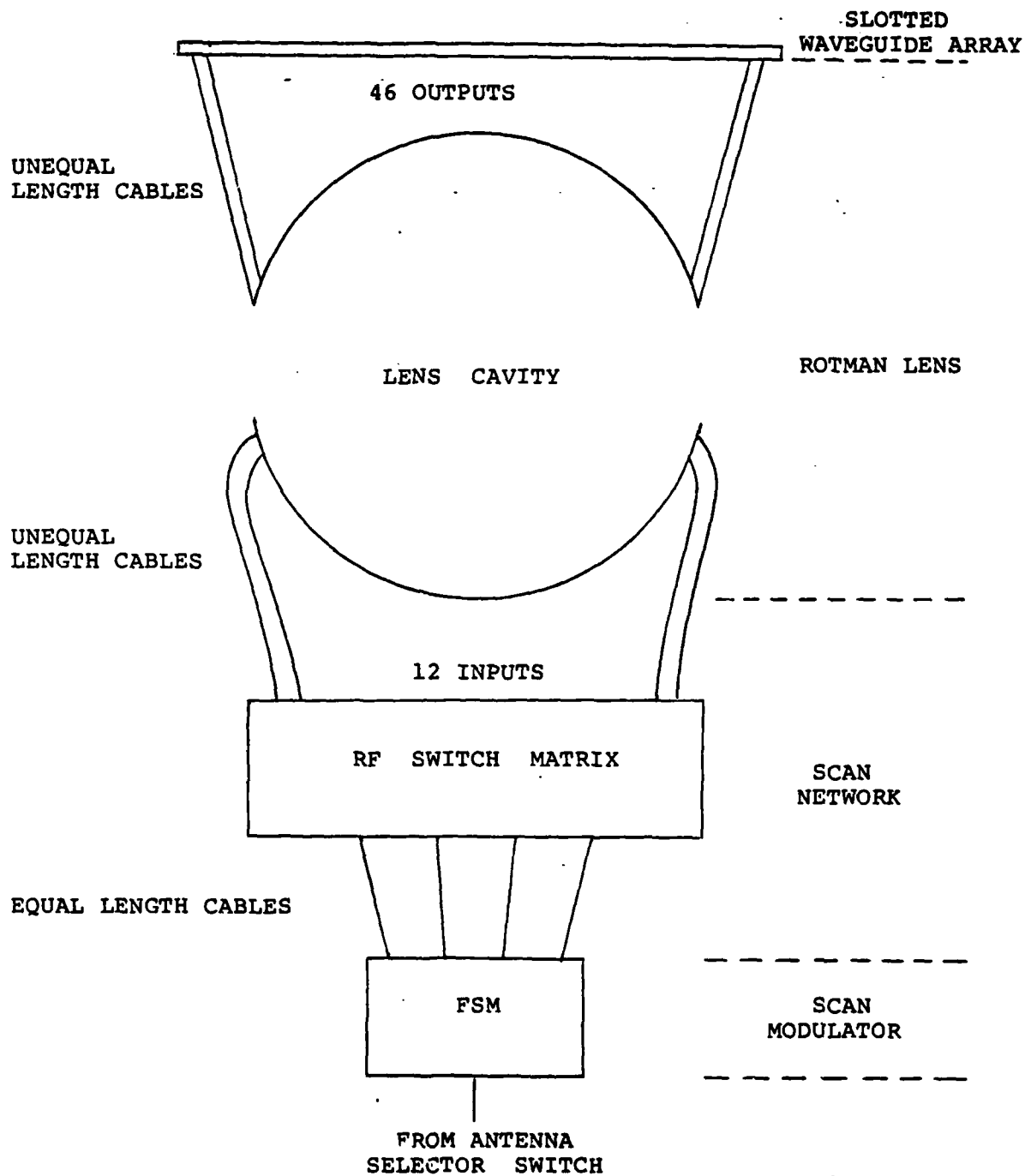


FIGURE 3-30. SC AZ SCANNING ARRAY

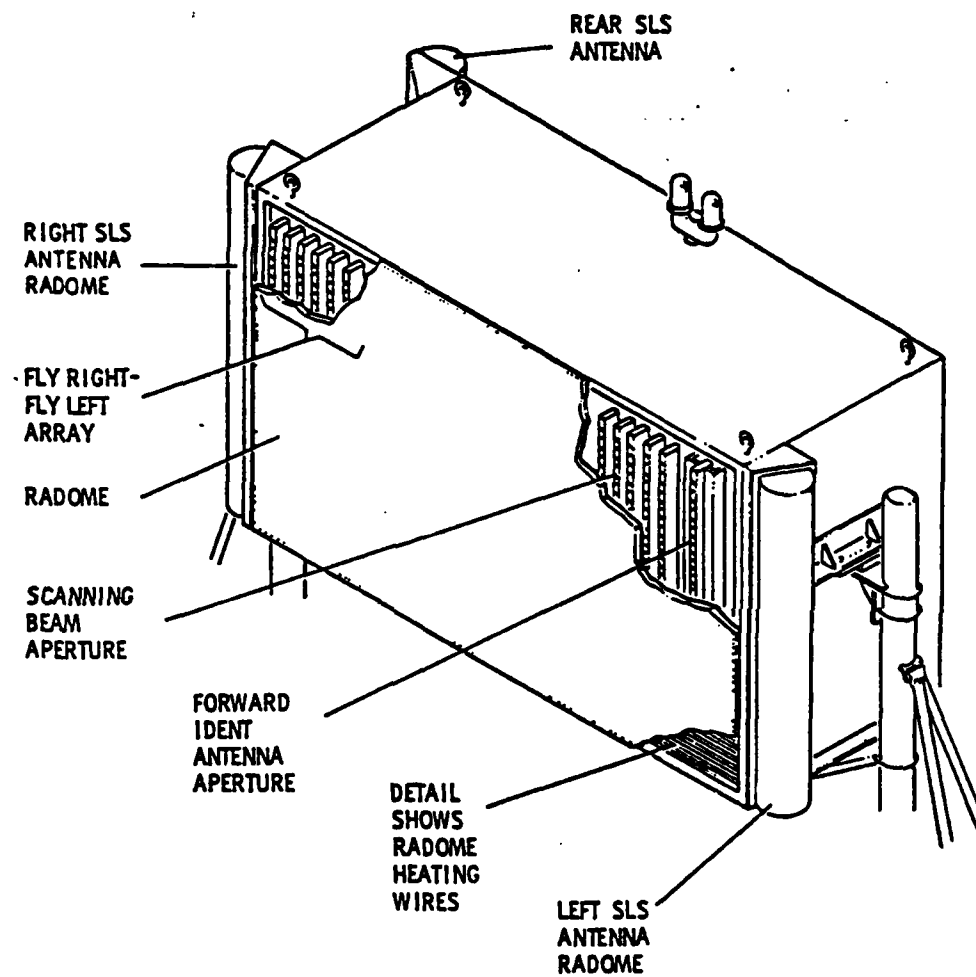


FIGURE 3-31. SMALL COMMUNITY AZ EQUIPMENT ENCLOSURE, FRONT VIEW

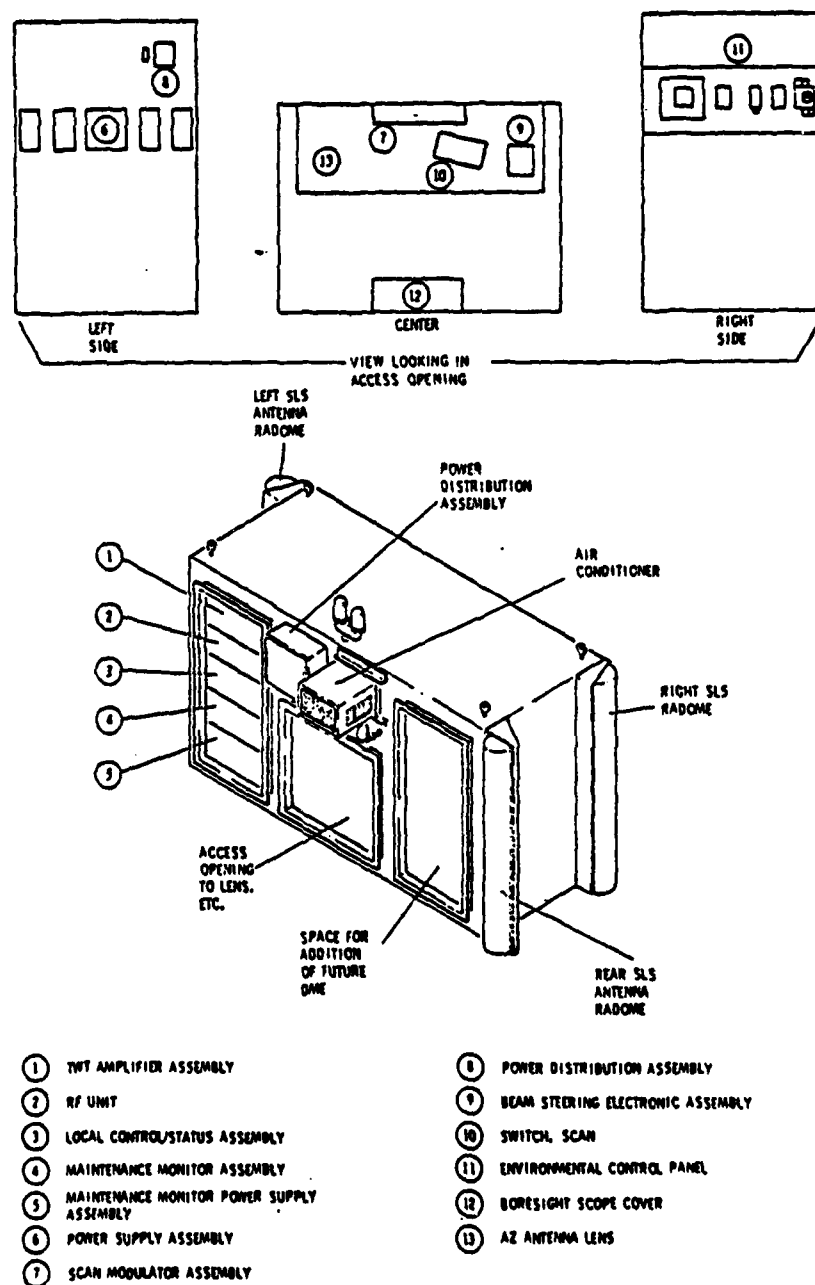


FIGURE 3-32. SMALL COMMUNITY AZ EQUIPMENT ENCLOSURE, REAR VIEW

12 INPUTS

46 ELEMENTS

$$\frac{d}{\lambda} = 0.50$$

$$\begin{aligned} F &= 0.74 \text{ m} \\ G &= 0.814 \text{ m} \\ R &= 0.581 \text{ m} \\ \alpha &= 40^\circ \end{aligned}$$

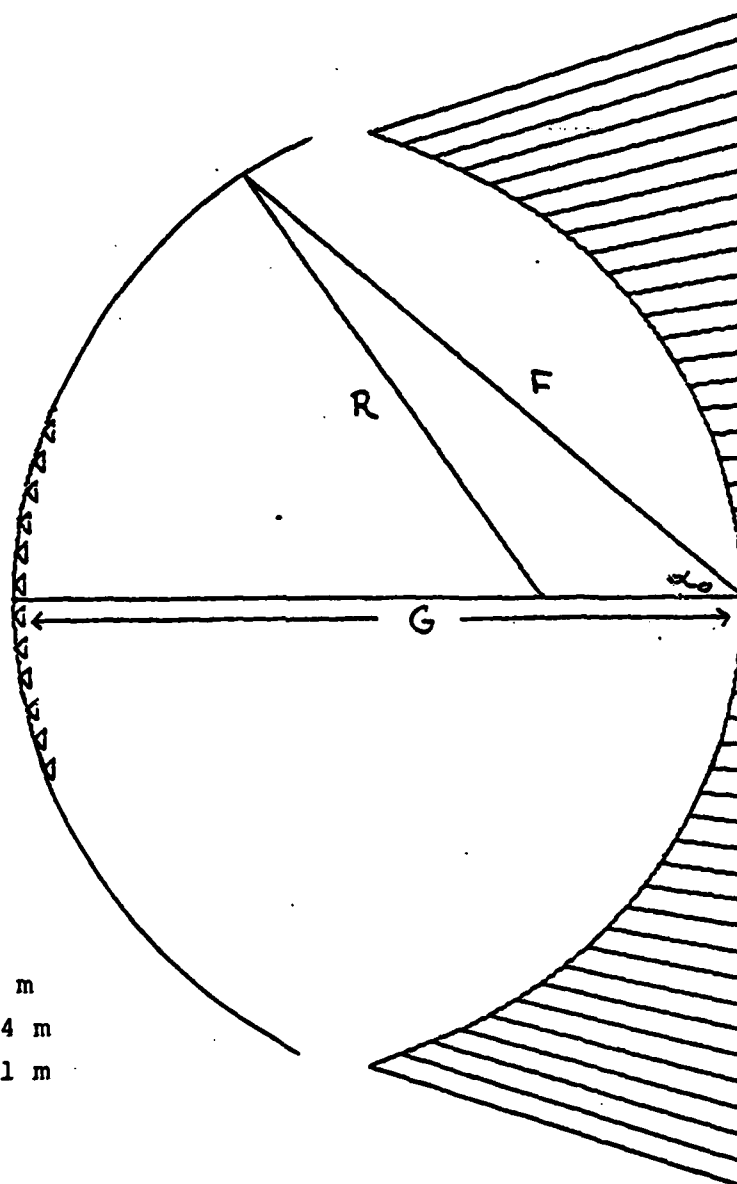


FIGURE 3-33. SC AZ ROTMAN LENS

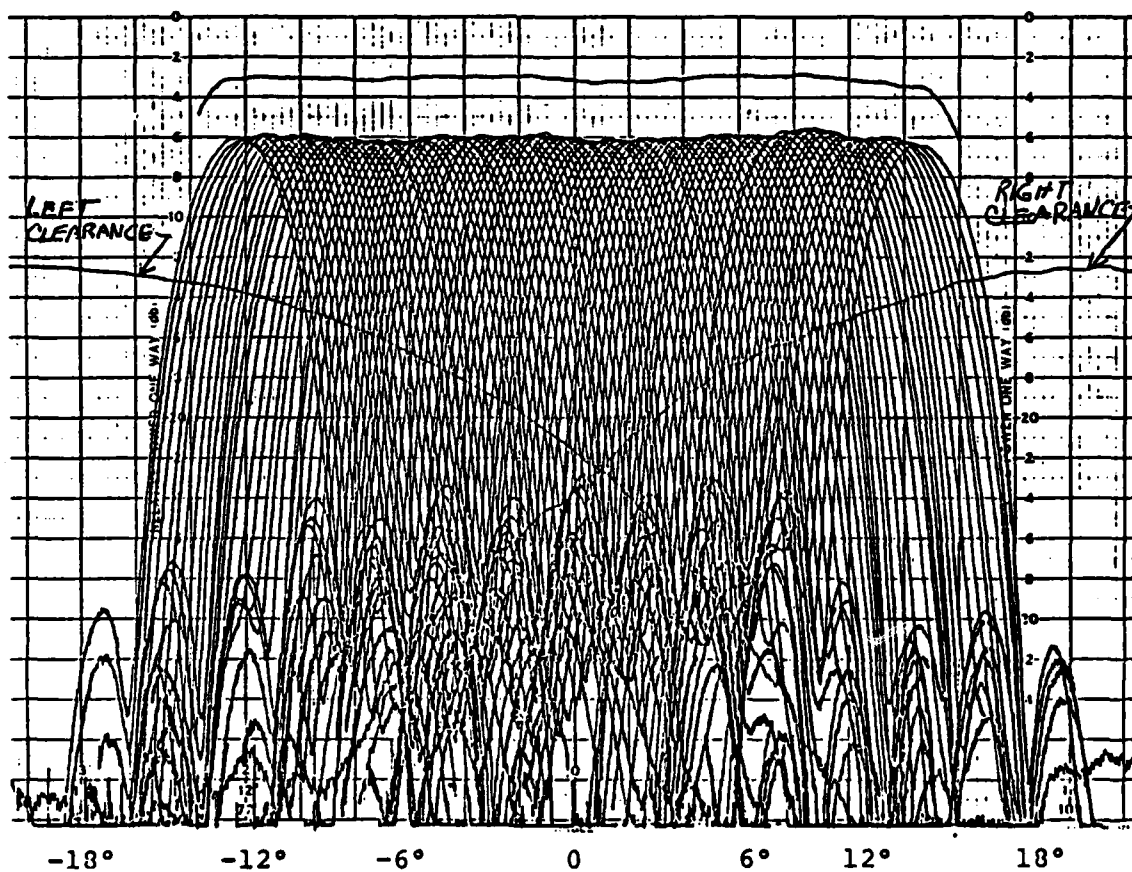


FIGURE 3-34. SMALL COMMUNITY AZ PATTERNS,
EVERY BEAM WITH OVERLAY OF RIGHT
AND LEFT CLEARANCE BEAMS

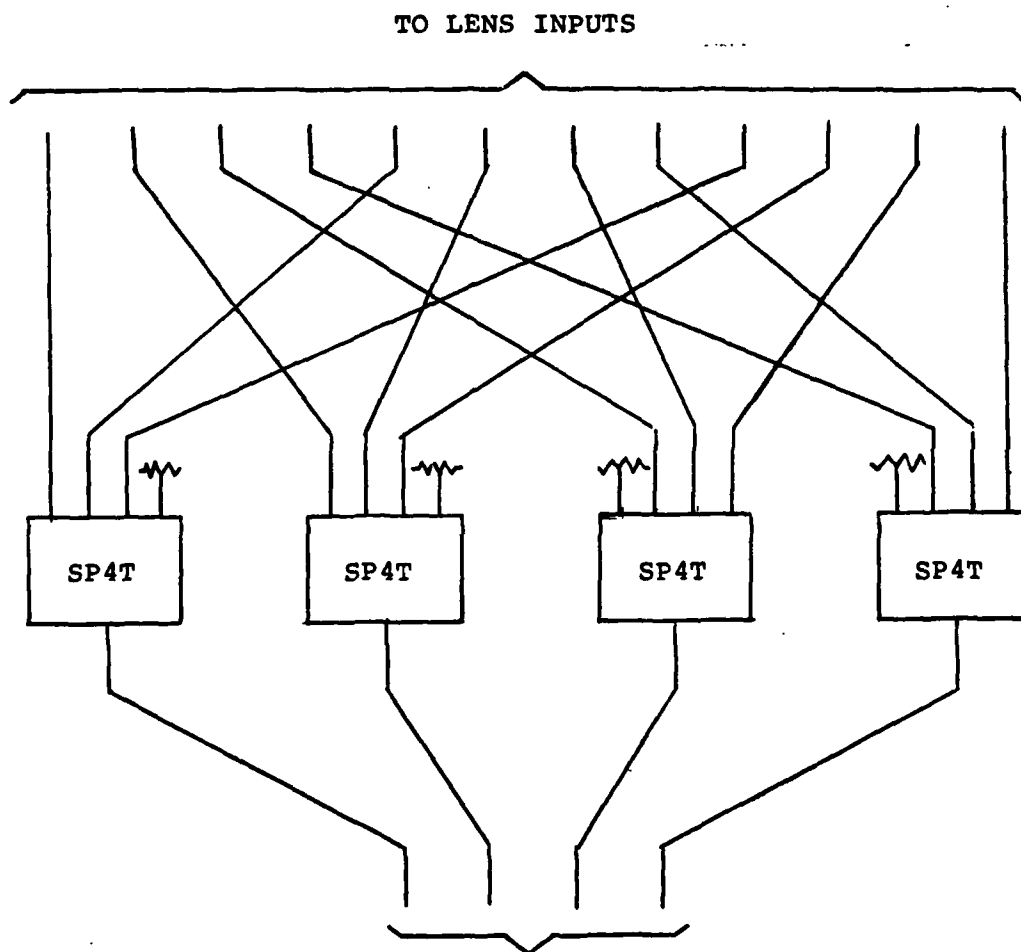


FIGURE 3-35. SC AZ SCAN NETWORK

3.3.1.1.5 Vertical Waveguide Array - The full AZ array aperture consists of 55 waveguide elements whose design is identical to that of the BN AZ array element. There is a dummy element on each end, 46 elements for the AZ scan beam, 6 elements for the fly left/fly right clearance beams, and a third dummy element between the scan beam array and the clearance beam array. The elevation pattern of the SC AZ antenna is identical to that of the BN AZ antenna, Figure 3-9.

3.3.1.2 Fly Left/Fly Right Antenna - The fly left/fly right guidance beam signals are generated by a small Rotman lens, Figure 3-36. The feed for this lens is shown in Figure 3-37. Each clearance beam is generated by feeding two lens inputs. The azimuth clearance beam patterns are shown in Figure 3-38. The elevation patterns are the same as the BN AZ scanning beam, Figure 3-10. The nominal antenna parameters are listed below:

Beamwidth	30 degrees
Sidelobes	≤ -16 dB
No. Elements	6
Spacing	$0.5\lambda_0$
Gain (at divider input)	17.3 dBi
Coverage	± 10 degrees to ± 40 degrees

3.3.1.3. Forward Ident Antenna - The forward ident beam is generated by a single vertical slotted waveguide whose design is identical to the rest of the waveguide elements in the array. This element is mounted at one end of the array and shares the radome used by the scan and clearance beam arrays. It has a separate shaped ground plane to obtain the required coverage. The pattern, measured in the array, is shown in Figure 3-39. The elevation pattern is the same as the BN AZ scanning beam, Figure 3-10. The gain is approximately 14.7 dBi. The asymmetry is due to the presence of the AZ array elements.

3.3.1.4 SLS Antennas - The SC AZ system has three sidelobe suppression antennas, each of which is identical to the BN AZ SLS antennas described in paragraph 3.2.1.3. The three antennas are boresighted at ± 80 degrees and 180 degrees in azimuth to provide complete azimuth sidelobe suppression coverage outside the ± 10 degrees proportional guidance error. (See Figure 2-24.)

3.3.1.5 Antenna Selector Switch - The SC AZ antenna select switch is comprised of two SP4T switches connected as shown in Figure 3-40. These switches are identical to the Basic Narrow AZ antenna select switch described in paragraph 3.2.1.4.

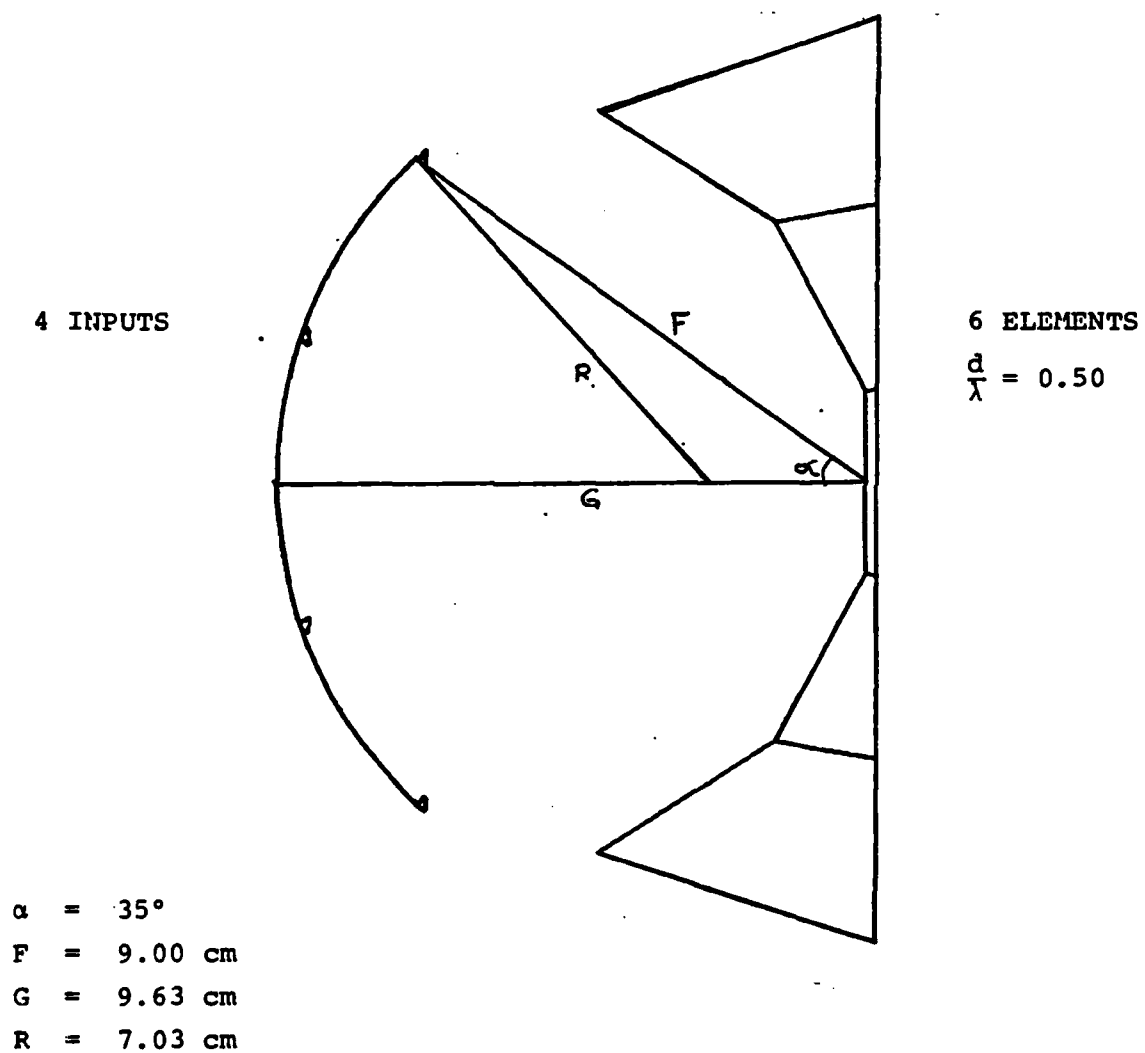


FIGURE 3-36. FLY RIGHT/FLY LEFT LENS ANTENNA

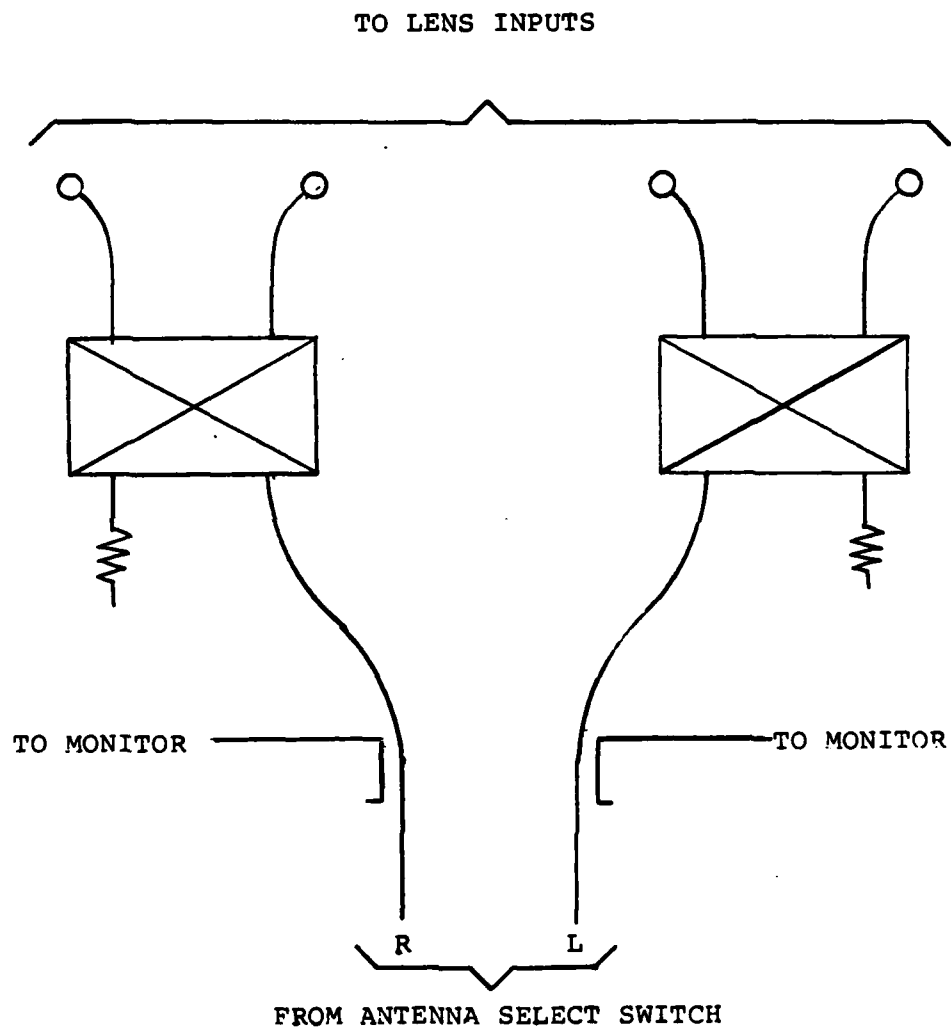


FIGURE 3-37. FLY RIGHT/FLY LEFT FEED NETWORK

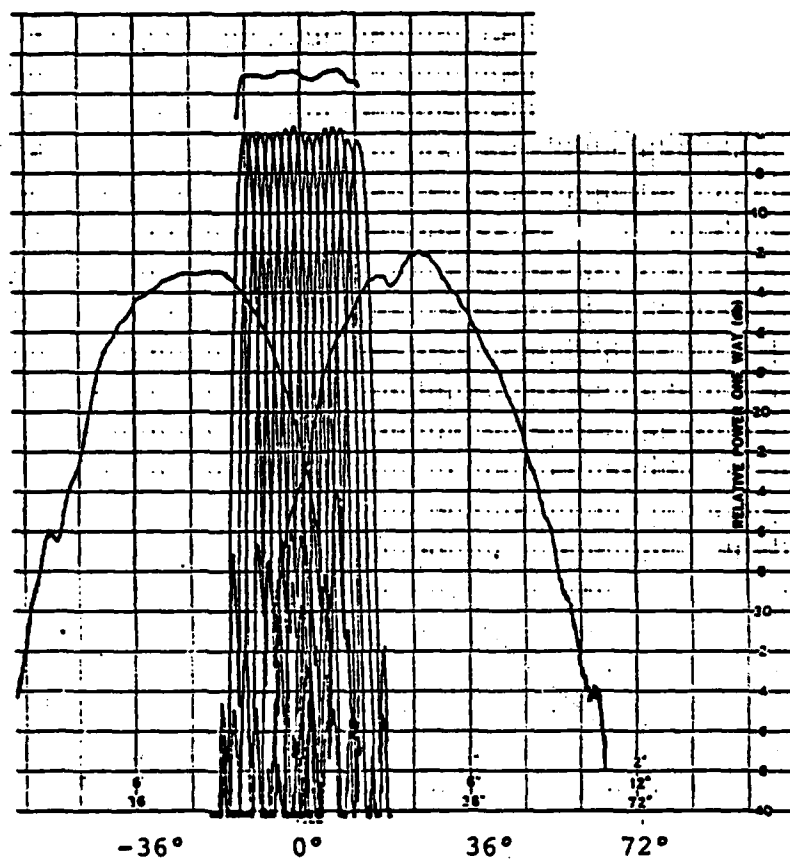


FIGURE 3-38. EVERY 10TH BEAM OF SMALL COMMUNITY AZIMUTH
WITH OVERLAY RIGHT AND LEFT CLEARANCE BEAMS

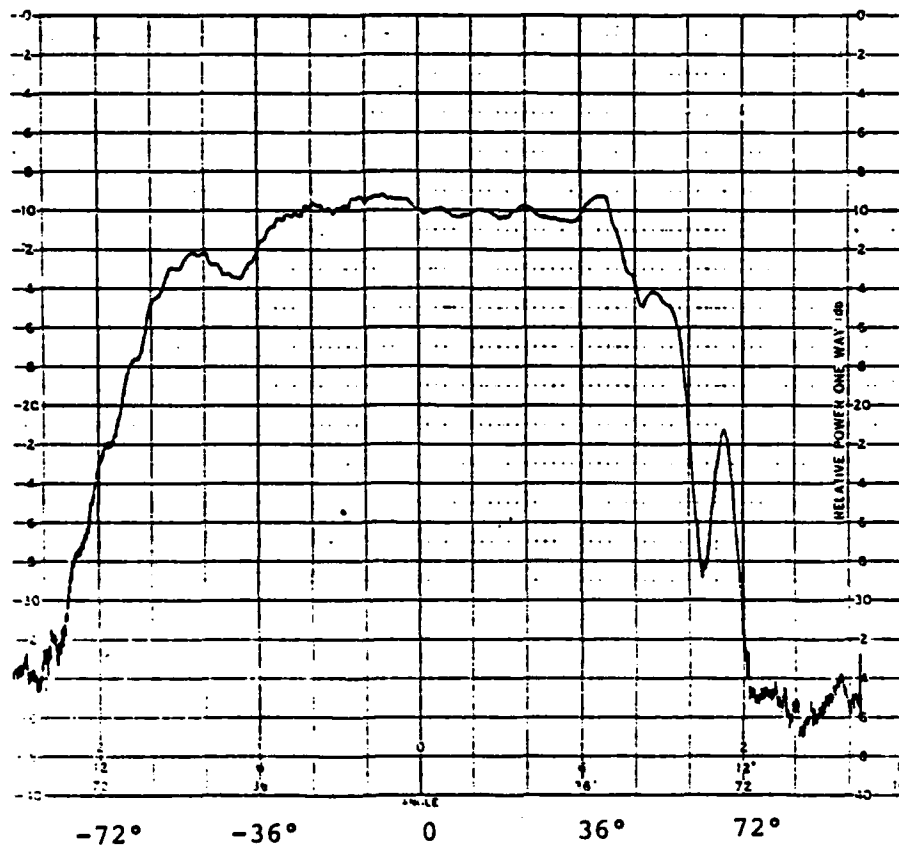


FIGURE 3-39. SMALL COMMUNITY AZ FORWARD IDENT
ANTENNA AZIMUTH COVERAGE

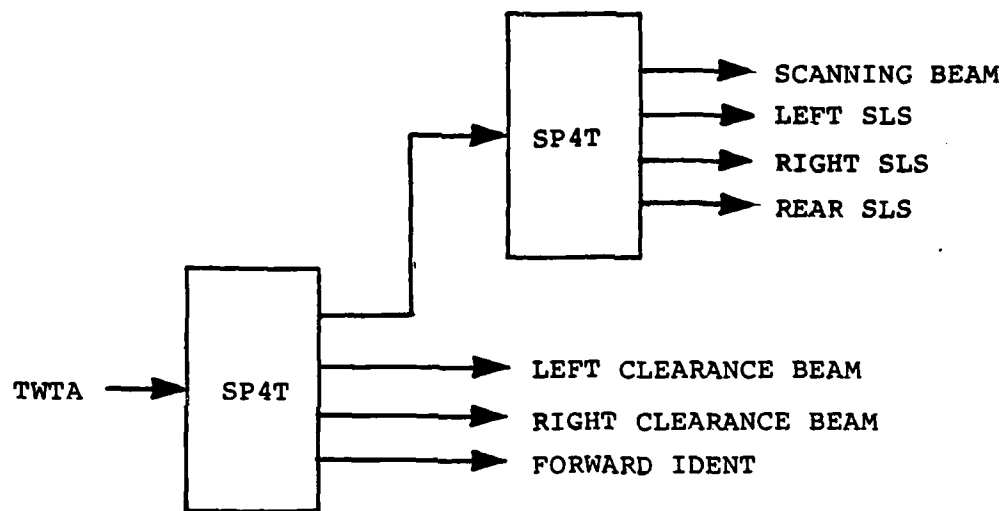


FIGURE 3-40. SMALL COMMUNITY AZ ANTENNA SELECT SWITCH

3.3.1.6 Beam Steering - The beam steering equipment provides control signals to the scan network switches and the fine scan modulator which steer the antenna beam in the required azimuth TO-FRO sequence. A schematic of the beam steering equipment is shown in Figure 3-41. This equipment is similar to the Basic Narrow AZ beam steering equipment, but contains less electronics since the azimuth scan angle (hence the number of RF switches in the scan network) is less in the Small Community system than the Basic Narrow system.

Functionally, this equipment can be divided into two sections, control and monitor. The control section develops the signals which actually control the beam scan while the monitoring section develops duplicate on-line signals and compares the two sets of signals to ensure that proper steering control is being achieved.

3.3.1.6.1 Control Section - The scan control and scan switch driver circuitry comprise the control section. The scan sequence is controlled by the scan and pause gates, that is, the TO-scan continues until terminated by the pause gate, and the FRO-scan continues until terminated by the end of scan. There are 12 feeds, spaced at 3-degree intervals, which are energized. The pause gate terminates the TO-scan and inhibits the scan for a predetermined period of time and then starts the FRO-scan.

The fine count, used for the 0.3-degree scanning increments, is derived by dividing the 10-MHz clock down to 100 kHz. The coarse count of 10 kHz, used for the 3-degree scanning increments, is derived via a further 10:1 division.

To compensate for the scan being non-linear with time as the beam is steered away from the centerline of the runway, the 100 kHz boresight frequency must be modified for each coarse scan position. Assuming position five corresponds to the center of the runway, each beam position between 5-10 and 5-0 gets a frequency compensation factor inserted into the nominal 100-kHz frequency. This provides a constant 20,000-degree/second scan.

A PROM circuit is used in the scan control PC board to develop the switching sequence for the four scan switches. To provide better noise immunity, differential drivers are used to drive the switch transmission lines. Therefore, each differential driver transmits two signals (A and B) for four lines to an associated differential receiver at each of the four scan switches.

The scan control also generates the 6-bit signal which controls the fine scan modulator.

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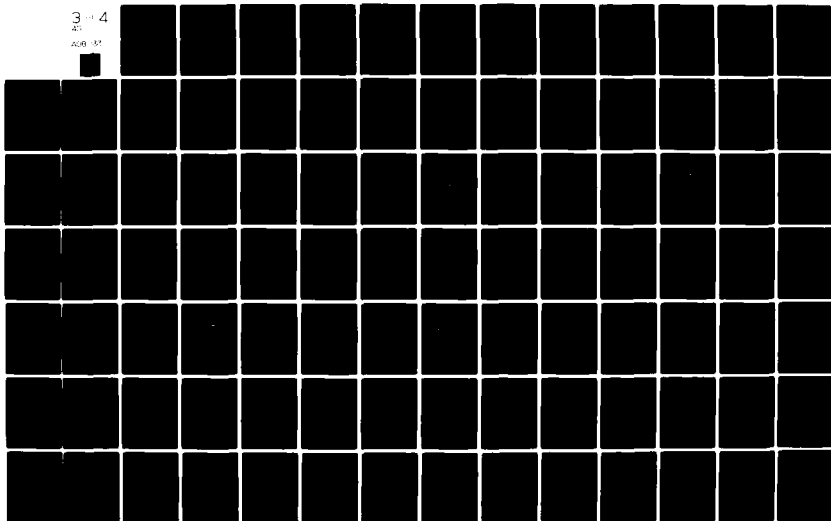
BENDIX CORP. BALTIMORE MD COMMUNICATIONS DIV
MICROWAVE LANDING SYSTEM (MLS). PHASE III. (BASIC NARROW & SNAL--ETC(U)
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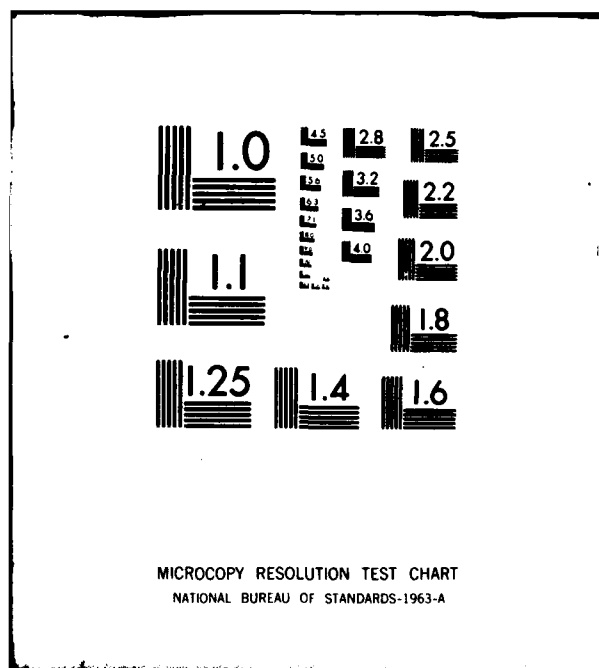
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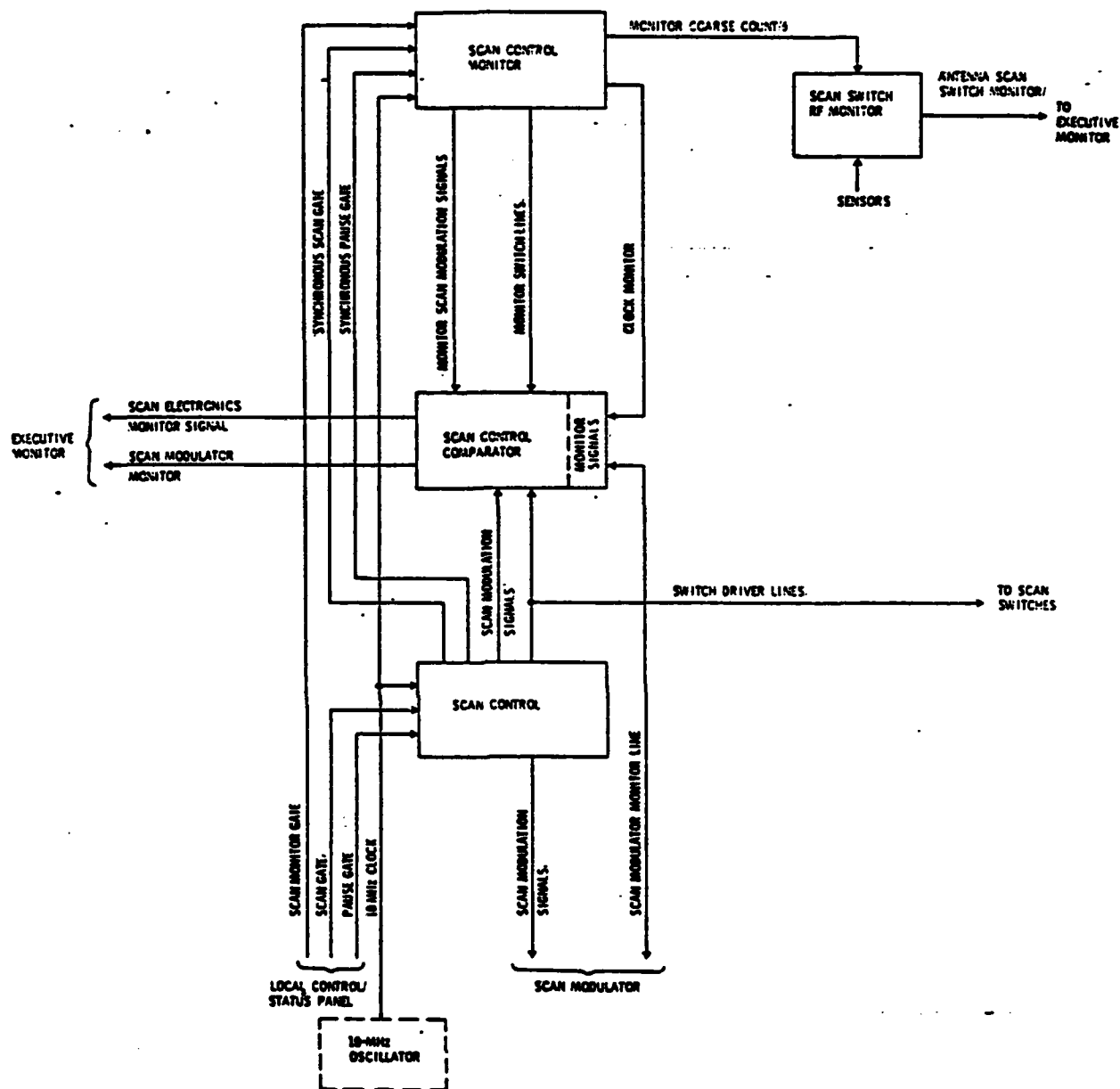


FIGURE 3-41. BEAM STEERING BLOCK DIAGRAM

The 10-MHz oscillator is accurate to 1 part in 10^6 over the temperature range from -20 degrees C to + 70 degrees C.

3.3.1.6.2 Monitor Section - The scan control monitor, scan control comparator, and the scan switch RF monitor comprise the monitor section. The scan control monitor is similar to the scan control in that many of the same signal types are generated. These signals are used throughout the Beam Steering and Monitor assembly for monitoring by comparing these signals with signals generated by the scan control. The comparison for these signals is accomplished in the scan control comparator.

There are three monitor signals generated and fed to the executive monitor: (1) antenna scan switch RF monitor, (2) scan modulator monitor, and (3) scan electronics monitor. To provide better noise immunity, differential line drivers are used to drive these interfacing monitor signal transmission lines. The antenna scan switch monitor signal is developed by monitoring the RF energy out of the scan switches. Four sensor signals, one signal for each scan switch output jack, are developed for each of the four scan switches. These signals are OR'ed and multiplexed to form a composite signal which is sent to the executive monitor as the antenna scan switch monitor. The RF output of the scan modulator is monitored internally. Therefore, the scan modulator monitor signal is developed in the scan modulator and then applied to the Beam Steering and Monitor assembly, from where it is sent to the executive monitor. The scan electronics monitor signal, which is fed to the executive monitor, provides an overall check of the antenna control system. This signal is developed by OR'ing the comparator circuits for the following five separate monitoring functions.

- a. Scan modulator control input: This 6-bit binary number originates in the scan control. Duplicate signals are developed in the scan control monitor. The two groups of signals are then compared in the scan control comparator to form a single monitoring signal.
- b. Driver signals for scan switches. These 16 lines originate in the scan control. Duplicate signals are developed in the scan control monitor. The two groups of signals are then compared in the scan control comparator to form a single monitoring signal.
- c. Nominal 100 kHz count frequency: This signal is developed in the scan control and a duplicate signal is developed in the scan control monitor. These two signals are compared in an exclusive OR circuit to form a single monitoring signal.

- d. 10-MHz clock: The 10-MHz crystal oscillator output is monitored in the scan control monitor to determine if logic-level 10-MHz signals are present.

In addition to these interfacing monitoring signals, which when activated shut down the system; there are several other monitoring circuits which activate fault indicators in the scan control comparator and monitor. These monitoring circuits include a fault indicator for each of the scan switches, a composite scan switch error fault indicator, a 10-MHz clock fault indicator, and fault indicators for the scan modulator, nominal 100 kHz, scan electronics, and a scan control fault indicator which monitors the scan modulator input and scan switch drivers 1-4.

The scan switches are monitored by the scan switch monitor. The scan switches are monitored sequentially, 1 through 4, during each antenna scan. If a faulty switch is discovered, the associated switch fault indicator is activated, the monitor clocks are inhibited, and a fault is indicated. Thus, the faulty switch can be easily identified. A scan monitor gate inhibits the monitoring of the switch sensor signals during any portion of the scan interval where the RF energy is turned off to avoid erroneous fault indications.

3.3.1.7 TWT Amplifier - The TWT amplifiers for the SC system are Litton Model 654. Electrically, they are identical to the BN TWT amplifiers, Model 653 (paragraph 3.2.1.6), except that the power input specification is 112 to 132 V at 47 to 63 Hz.

3.3.1.8 RF Unit - The SC RF unit is identical to that used in the BN system (paragraph 3.2.1.7).

3.3.1.9 Local Control/Status - The Local Control/Status for the Small Community is very similar functionally to that for the Basic Narrow system. A functional block diagram is shown in Figure 3-42. This is identical to the Basic Narrow block diagram, Figure 3-15, with the exceptions being that the Small Community does not have DME or variable auxiliary data capability. Other than this, the description of paragraph 3.2.1.8 applies to this equipment also.

3.3.1.10 Remote Status - The Remote Status assembly is currently located in the AZ equipment enclosure, but would normally be located in the ATC tower cab. This unit provides a status indication to the remote operator, but does not provide control functions.

The Remote Status normally operates over telephone cable which can be connected to either the AZ or EL site. It is an

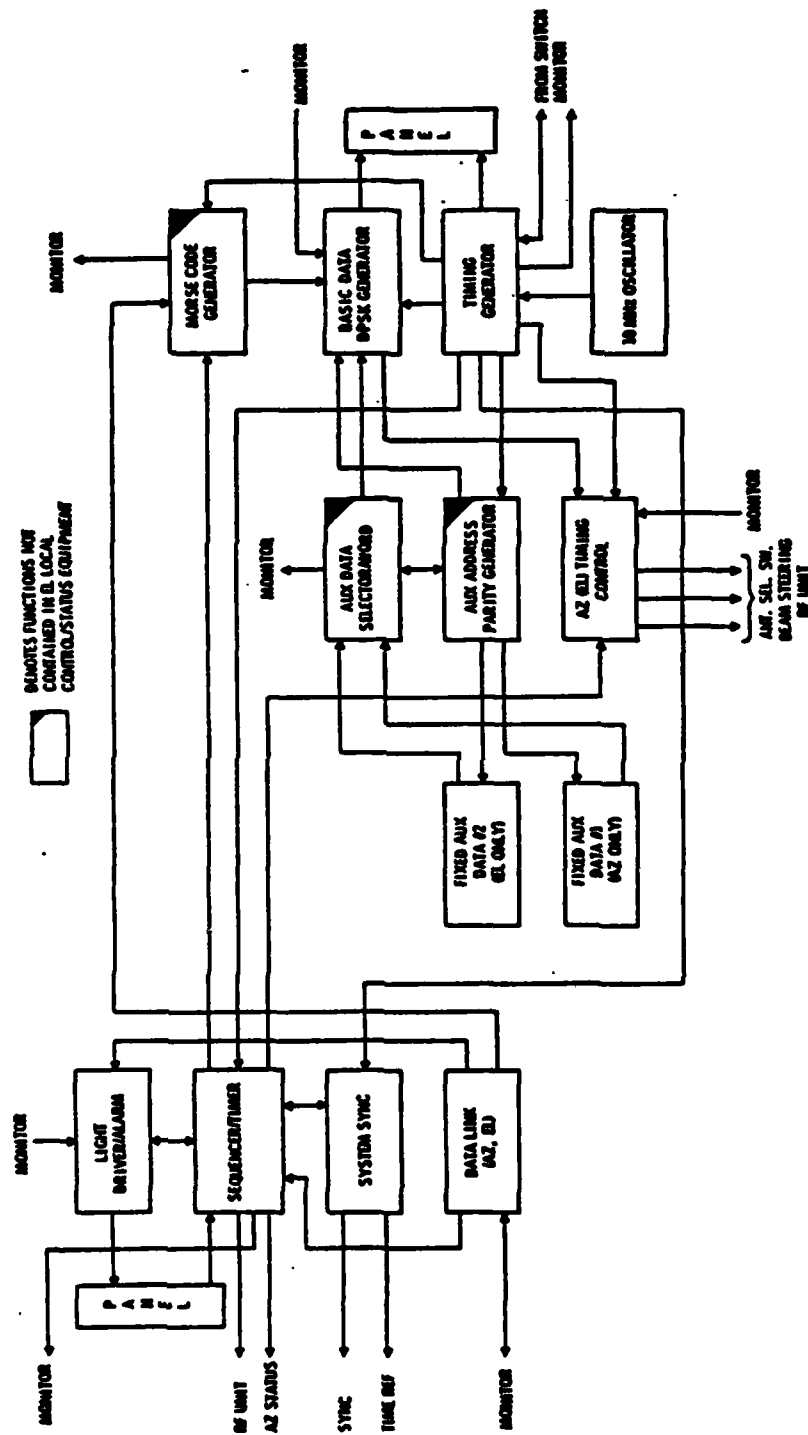


FIGURE 3-42. SMALL COMMUNITY LOCAL CONTROL/STATUS FUNCTIONAL BLOCK DIAGRAM, AZ AND EL

independent unit with the only power input requirement being 120 V ac. The following functional operations are provided by this assembly.

- a. The on/off status, the executive, maintenance, and data link malfunctions status for both AZ and EL subsystems are provided. All of these functions are displayed on the system status display.
- b. The station identification code monitor allows the stations' identification code (Morse code), being transmitted by the azimuth transmitter to be monitored at the operators' discretion via an on/off switch.
- c. Incorporated with the station identification code monitor is an aural alarm system. This alarm system overrides the Morse code monitor, regardless of system status at any time. Whenever one of the subsystems develops an executive error and goes off the "air" the aural alarm may be silenced only by clearing the fault or via the alarm off switch. When the alarm off switch is used, the alarm off lamp blinks as a visual warning that the aural alarm has been disabled.
- d. The status display lamps are tested via a front panel mounted double action switch. When this switch is placed in the opposite direction, it serves as the aural alarm test.
- e. A front panel mounted lamp dimmer control is provided for adjusting the brilliance of the STATUS DISPLAY lamps to a comfortable level relative to the room lighting conditions.

The Remote Status assembly contains the lamp and aural alarm circuit, lamp dimmer circuits, aural alarm sweep oscillator, Morse code and monitor amplifier, and the visual alarm indicator.

3.3.1.11 Monitor

3.3.1.11.1 General - Each critical piece of equipment in the AZ subsystem provides one or more signals which are sent to the monitor equipment for processing. Paragraph 2.4.5 described the use of these signals. In this section, the generation of these signals will be discussed. The executive monitors will be discussed first (refer to Table 2-26).

Due to the similarity between the AZ and EL monitoring, the description will apply to either; when differences exist, they are specifically called out.

3.3.1.11.2 Executive Faults - The field monitor for AZ is used to check beam accuracy, beam ERP, and test pulse accuracy. This monitor checks overall site performance and is not just an indication of antenna subsystem performance. Many failures occurring in the antenna subsystem will be indicated as a beam accuracy or beam ERP failure. However, other failures in the ground electronics equipment will also cause beam accuracy and beam ERP indications. Generally, when antenna subsystem failures cause beam accuracy or ERP indications, other antenna subsystem faults will also be indicated. The ERP measurement is made by sampling the peak power in the beam as it scans past the field monitor horn. The measurement is made using an RF detector and a video amplifier at the field monitor horn. Processing of the video is accomplished by the monitor subsystem. The ERP of the forward ident, fly right, fly left, left SLS, right SLS, and rear SLS are executive monitor points. The radiated power at the aperture of each antenna is sampled, RF detected, video amplified, and sent to the Maintenance Monitor for processing. The beam accuracy measurement is made by sampling the RF energy of the TO-FRO beams at the field monitor horn, and sending this sample back to the monitor subsystem at the electronics equipment shelter for processing.

Within the antenna subsystem, there are three executive monitors on the scanning beam antenna (see paragraph 3.3.1.1 for AZ and 3.3.2.1 for EL): (1) scan switch monitors, (2) fine scan modulator monitor, and (3) scan control monitor. Each scan switch on the lens assembly (4 for EL and 4 for AZ) is fully monitored using an integral RF detector diode/probe at each switch output (4 per switch). At the proper time, the output video from this diode is sampled and compared to a predetermined threshold. The logic for controlling the switch monitors is contained in the beam steering assembly. For a given antenna, a single transistor-transistor logic (TTL) signal is transmitted, indicating the combined status of the switches. An indication of the failed switch by number is presented via a light-emitting diode (LED) in the Switch Monitor located in the Beam Steering Electronics subassembly.

The fine scan modulator has an integral monitor which checks the status of each phase shifter bit within the modulator. A single TTL signal output to the Beam Steering Electronics subassembly indicates the status of the fine scan modulator. This single output also indicates the status of the heaters within the fine scan modulator. A fault will be indicated if the heater circuit opens or, at initial turn-on, until the unit reaches the required operating temperature.

The Beam Steering Electronics subassembly is fully monitored via duplication and comparison of beam steering functions. A

single failure indication (SCAN CONT) is sent to the monitor subsystem. (See Figures 3-41 for AZ and 3-48 for EL).

In the EL antenna, the ERP monitors on both the forward ident and upper SLS antenna are executive monitor points. The radiated power at the aperture of these antennas is sampled, RF detected, video amplified, and sent to the Maintenance Monitor subsystem for processing.

Errors in the preamble are detected by comparing the serial DPSK data, collected by the sampling probe in the forward ident antenna aperture, with equivalent digital data generated independently by the DPSK monitor. Data bit mismatches are detected and segregated into several classifications leading to executive or maintenance fault indications. A mismatch in either the Barker code, ID code, or the data will produce an executive fault indication unless the ID code indicates that Basic Word Data is being transmitted. In this case, a mismatch in the Barker or ID codes produces an executive fault indication; a mismatch in the data word produces a maintenance fault indication.

To monitor site frequency, use is made of the 10-MHz clock signal and the exciter oscillator output signal, which is the final frequency divided by 50. This circuitry operates at a 15 kHz offset representing zero frequency.

The beam accuracy and test pulse accuracy are measured in a similar manner. Samples of the TO-FRO beam are supplied by the field monitor, and samples of the test pulses are supplied by the forward ident antenna aperture probe. These outputs are monitored by thresholding the detected RF and counting the number of precision clock pulses between the leading edge of the TO beam (or first test pulse) and the trailing edge of the FRO beam (or second test pulse). This count is compared to an anticipated count. The error is provided as an 8-bit word for pointing error (0.004 degree resolution for AZ, 0.002 degree for EL), or a 5-bit word for test pulse spacing.

3.3.1.11.3 Maintenance Faults - The maintenance monitors for both the AZ and EL antenna enclosures are the case temperature, +5 VDC, +15 VDC, -15 VDC, +20 VDC, +24 VDC, and -40 VDC power supplies. A thermistor element is used to sense temperature, and a temperature alarm is indicated on the monitor front panel when the temperature exceeds either +50°C or -10°C.

The generation of a maintenance fault for Basic Data Words No. 1 and No. 2 was described in the previous section.

Since the monitor subsystem has its own power supplies these are also monitored and include two +5 volt supplies, a +15 volt supply, and a -15 volt supply.

Internal monitors within the RF unit (paragraph 3.2.1.7) provide the status of the exciter output, the amplitude modulator, and the phase modulator.

The TWT amplifier has a coupler at the output which samples the output power level (paragraph 3.2.1.6).

In the EL subsystem, a maintenance fault is indicated if the system sync pulse is not present. An executive fault is indicated if the EL to AZ sync difference is greater than 100 μ s.

3.3.1.12 Antenna Case - Major components in the AZ antenna case are shown in Figure 3-32. The case houses the AZ scanning beam antenna and associated steering electronics along with the ground electronics subsystem. The antenna case is a waterproof metal structure measuring 96 inches wide, 64 inches high, 42 inches deep, and with the housed equipment weighs approximately 1900 pounds. To protect the antenna aperture, the front of the antenna case is fitted with a sandwich type radome made of fiberglass reinforced polyester. This material consists of two fiberglass reinforced skins over a honeycomb core. The "sandwich" is approximately 0.58 inches thick. Deicing is provided with dissipative wire grids embedded in the radome outer skin and heated directly with line power. An access cover is provided on one side of the case to permit servicing. The access cover is held in place by several quick-release fasteners so that removal or replacement of a cover can be accomplished in seconds. Support poles on the case provide mechanical adjustment for alignment, and also for positioning the case a minimum of 3-feet off local ground for snow clearance. The antenna case also contains environmental control equipment which enhances equipment reliability by minimizing temperature and humidity extremes. Primary power for the radome deicing circuit and the internal equipment is controlled via two circuit breaker safety switches mounted to the rear side of the antenna case.

3.3.2 Elevation Equipment

3.3.2.1 Scanning Array

3.3.2.1.1 Description - The components comprising the SC EL scan array are shown in Figure 3-43. The theory of operation is identical to that described previously (paragraph 3.1.1.1.1) for the BN AZ antenna. Two views of the SC EL antenna case are shown in Figures 3-44 and 3-45. The nominal characteristics of the antenna are given below.

Beamwidth	2 degrees
Sidelobes	\leq -20 dB

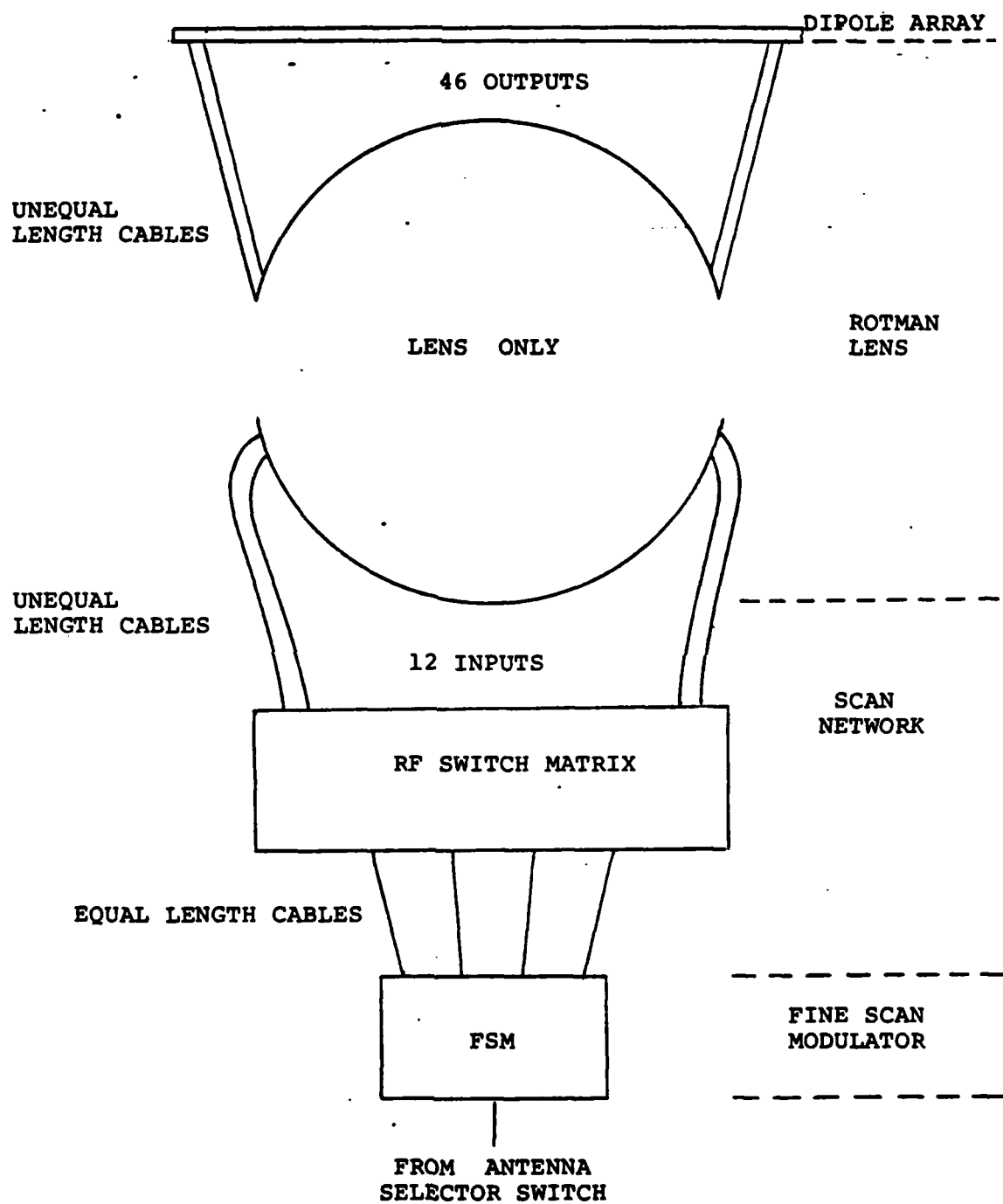


FIGURE 3-43. SC EL SCANNING ARRAY

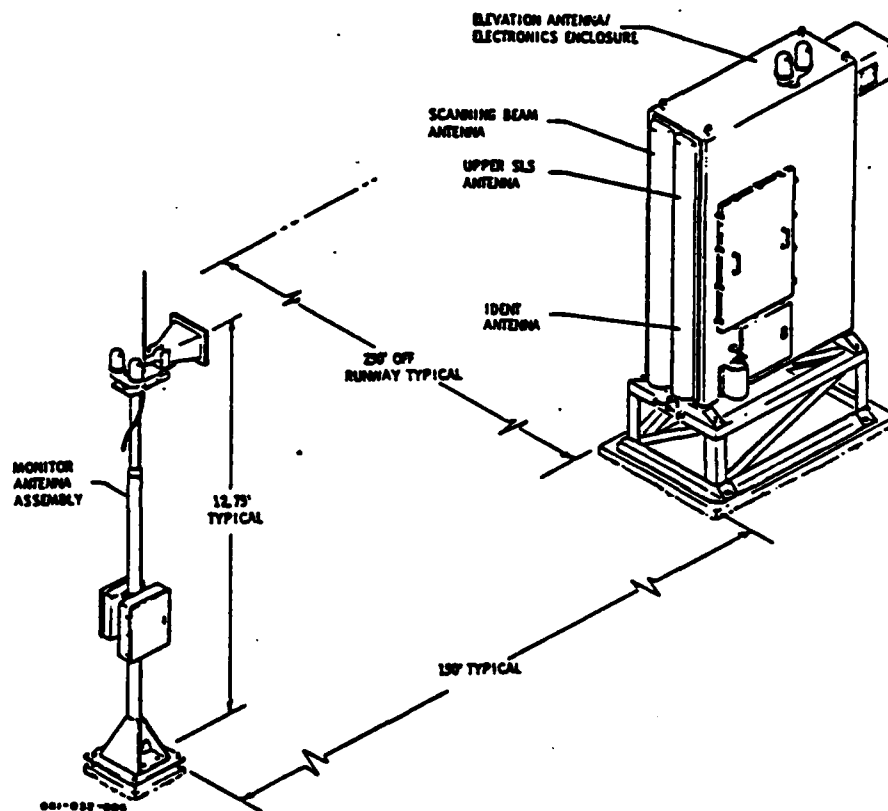
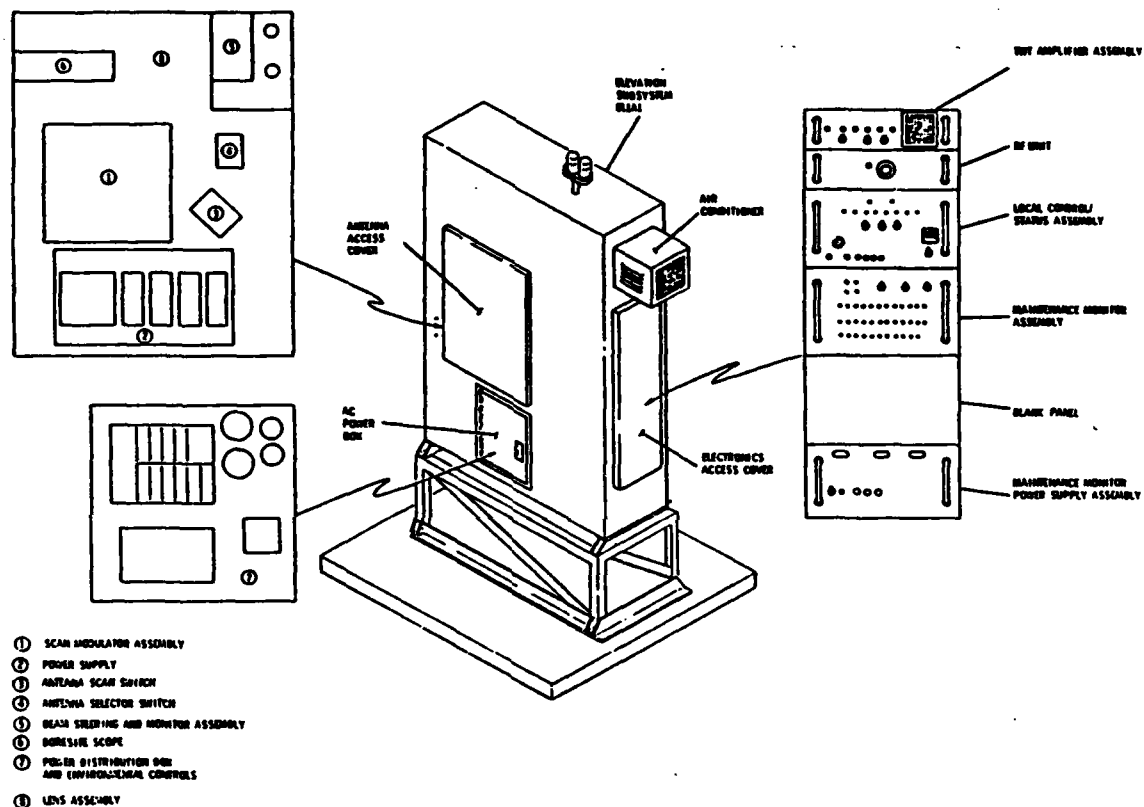


FIGURE 3-44. SMALL COMMUNITY ELEVATION EQUIPMENT



800-000-300

FIGURE 3-45. SMALL COMMUNITY EL SUBSYSTEM LAYOUT

No. elements	46 active + 2 parasite
Spacing	0.75λ
Start Angle	16.763 degrees
Stop Angle	0 degree
Fine Scan Steps	101
Gain (at FSM input)	20.3 dBi
Guidance Coverage	1 degree to 15 degrees

3.3.2.1.2 Rotman Lens - A schematic of the Rotman lens is shown in Figure 3-46. This lens is identical to the SC AZ array lens, but a different set of inputs is used. The lens incorporates a magnification of 1.5 (see paragraph 3.2.2.1.2), resulting in an element spacing of 0.75λ . The lens feeds a 46-element dipole array. Figure 3-47 is a composite showing every third beam in the step scan sequence. The azimuth pattern is the same as the BN EL azimuth pattern, Figure 3-26.

3.3.2.1.3 Scan Network - A schematic of the scan network is the same as that in the SC AZ array. Figure 3-25. The RF switches are identical to those of the BN AZ described in paragraph 3.2.1.1.3.

3.3.2.1.4 Fine Scan Modulator - The fine scan modulator is identical to that of the BN AZ described in paragraph 3.2.1.1.4.

3.3.2.1.5 Vertical Dipole Array - The dipoles are similar in construction to those in the BN EL scan array, and their azimuth patterns are identical to the BN EL, (see Figure 3-26).

3.3.2.2 Forward Ident Antenna - The SC forward ident antenna is identical to the BN AZ forward ident antenna described in paragraph 3.2.1.2.

3.3.2.3 Upper SLS Antenna - The SC upper SLS antenna is identical to the BN EL upper SLS antenna described in paragraph 3.2.2.3.

3.3.2.4 Antenna Selector Switch - The SC EL antenna select switch is identical to the BN EL antenna select switch described in paragraph 3.2.2.4.

3.3.2.5 Beam Steering - The Small Community EL Beam Steering block diagram is shown in Figure 3-48. It is functionally similar to the AZ beam steering equipment, except that EL has 16 RF switches, compared to 4 for AZ. Refer to paragraph 3.3.1.6 for a functional description.

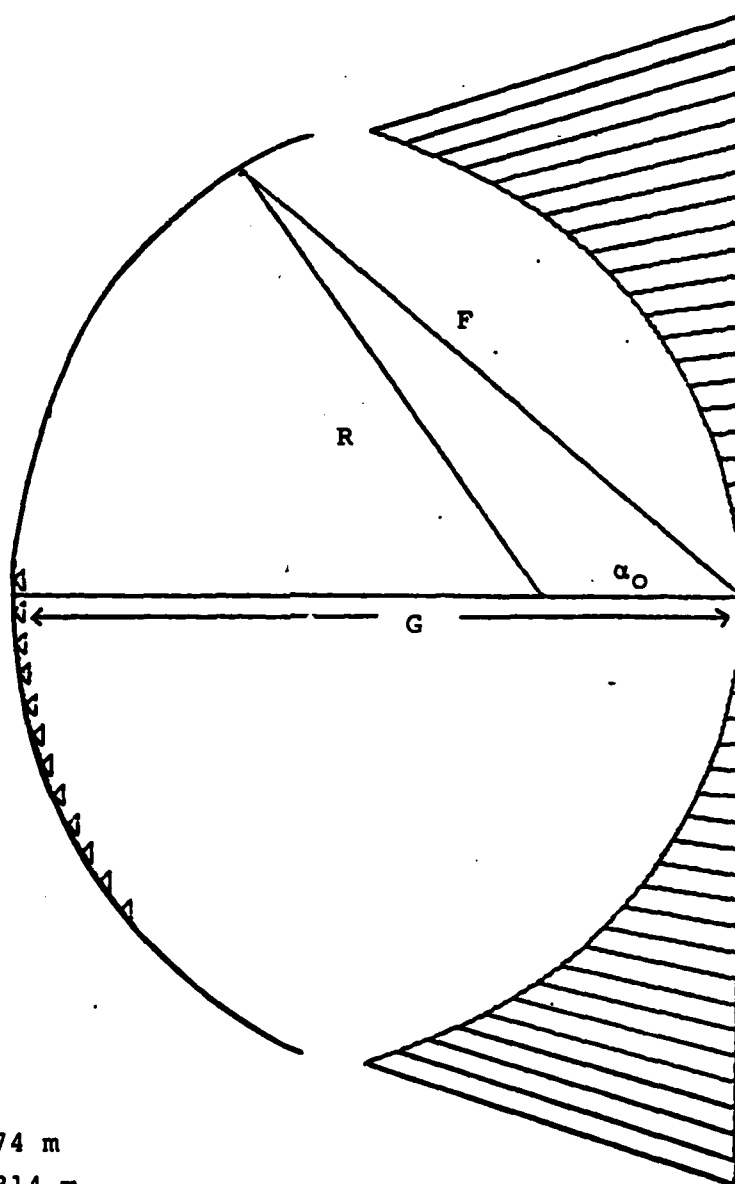
3.3.2.6 TWT Amplifier - This amplifier is identical to that used in the SC AZ system (paragraph 3.3.1.6).

3.3.2.7 RF Unit - The SC RF unit is identical to that used in the BN system (paragraph 3.2.1.7).

12 INPUTS

46 ELEMENTS

$$\frac{d}{\lambda} = 0.75$$



$$\begin{aligned} F &= 0.74 \text{ m} \\ G &= 0.814 \text{ m} \\ R &= 0.581 \text{ m} \\ \alpha_0 &= 40^\circ \end{aligned}$$

FIGURE 3-46. SC EL ROTMAN LENS

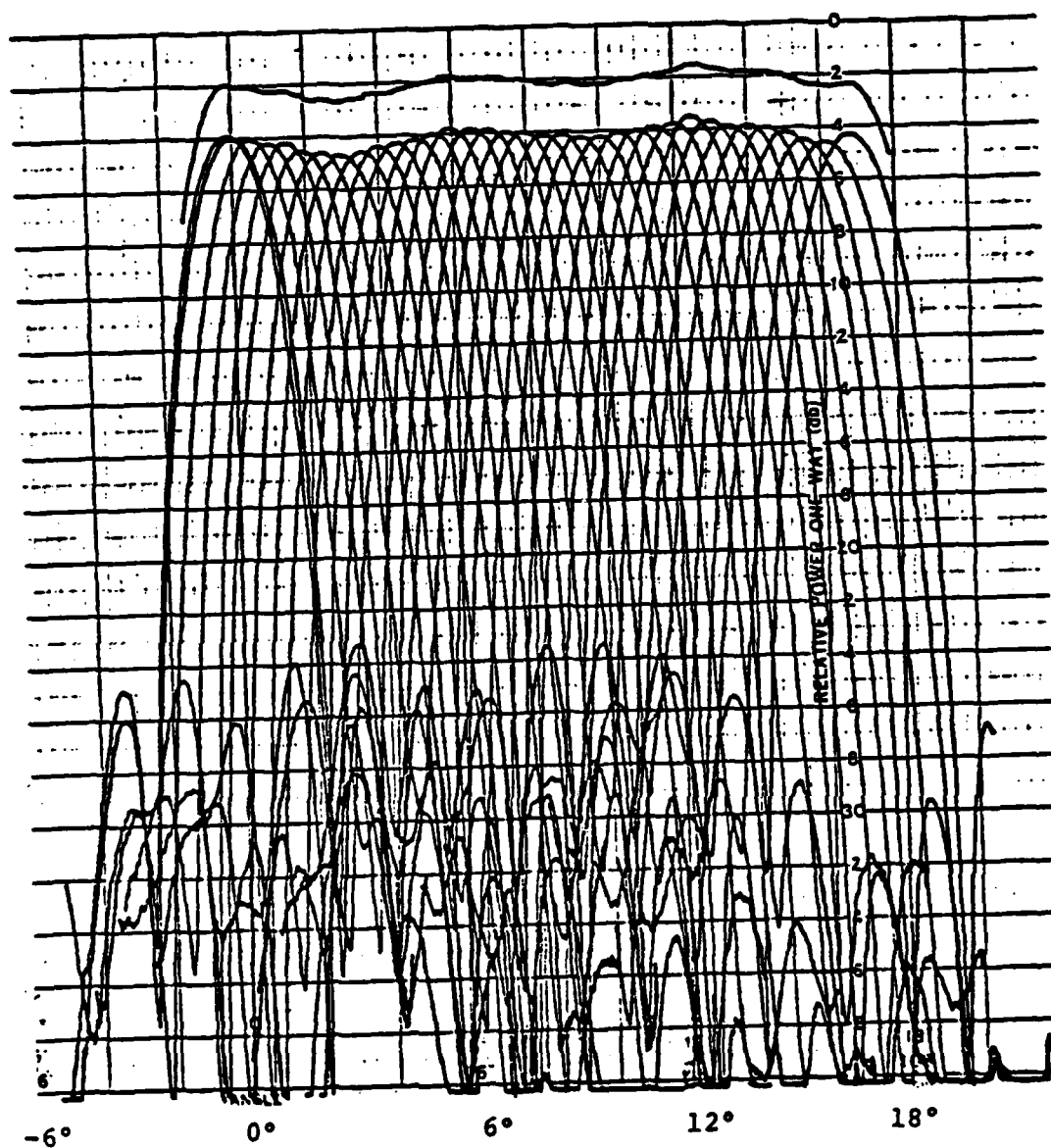


FIGURE 3-47. SMALL COMMUNITY EL ELEVATION PATTERNS,
EVERY 5TH BEAM

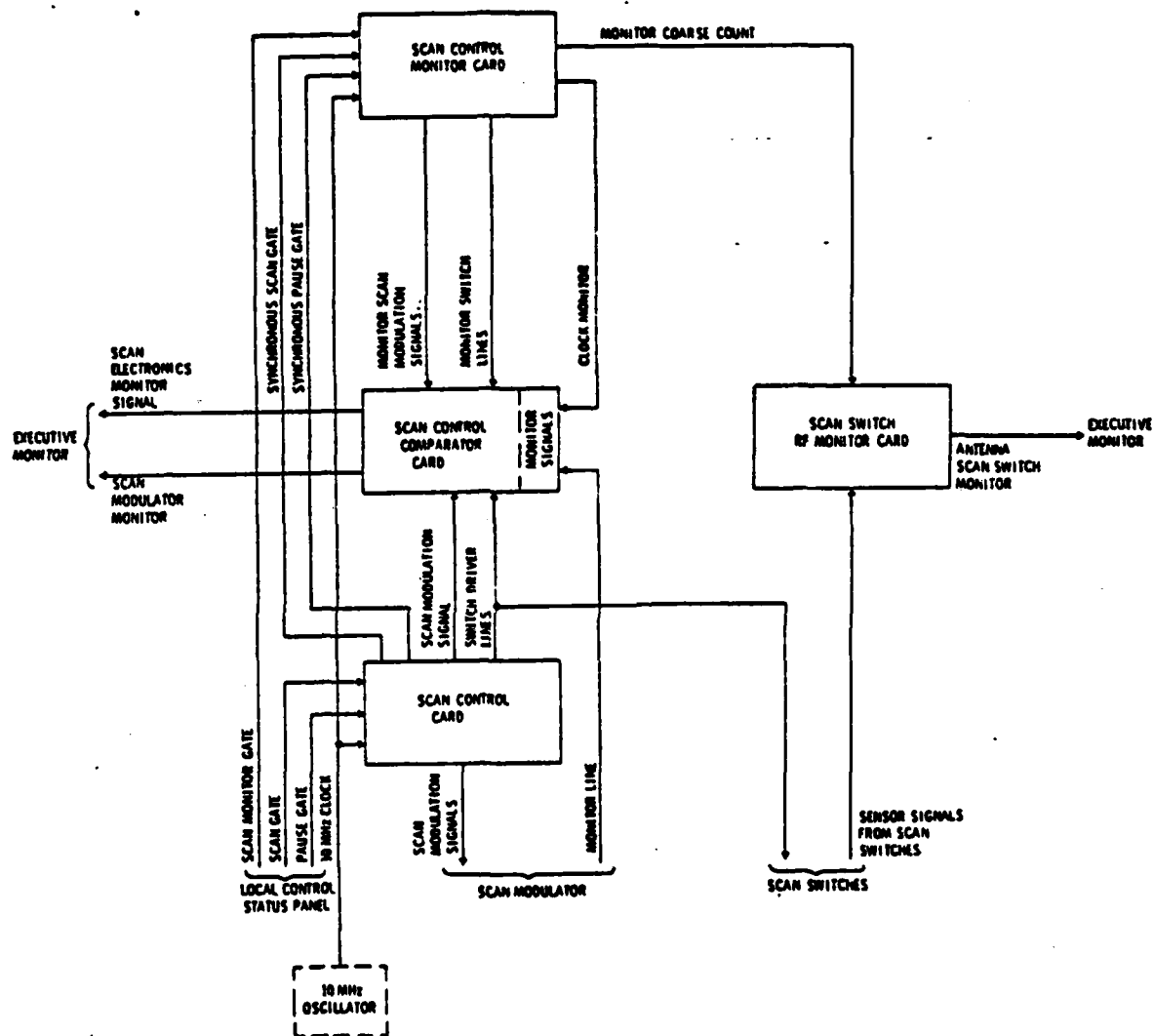


FIGURE 3-48. SMALL COMMUNITY EL BEAM STEERING
BLOCK DIAGRAM

3.3.2.8 Local Control Status - This equipment is described in paragraph 3.3.1.9.

3.3.2.9 Monitoring - The EL system monitoring was described along with the AZ system monitoring in paragraph 3.2.1.9. Except for the different parameters measured by each system, the design concept and operation of the AZ and EL monitors are identical.

3.3.2.10 Antenna Case - The EL antenna case (Figure 3-45) houses the elevation scanning beam antenna, the forward ident antenna, the upper SLS antenna, and the elevation ground subsystem electronics. The case is a waterproof metal structure measuring 92 inches high, 63 inches (plus 5 inches for radome) deep, 24 inches wide and with the housed equipment weighs approximately 1414 pounds. The forward ident and the upper SLS antennas are mounted to the case adjacent to the scanning beam aperture. To protect the antennas, the front of the antenna case is fitted with two cylindrical thin-wall type radomes made of fiberglass reinforced polyester. One radome protects the scanning beam antenna aperture while the second radome protects the forward ident and the upper SLS antennas. Deicing is provided with dissipative wire grids embedded in the radomes and heated directly by line power. Access covers are provided on one side of the case to permit servicing. The access covers are held in place by several quick-release fasteners so that removal or replacement of a cover can be accomplished in seconds. A pedestal support base provides mechanical adjustment for alignment, and also for positioning the case a minimum of 3 feet off local ground for snow clearance. The case also contains environmental control equipment which enhances equipment reliability by minimizing temperature and humidity extremes.

3.3.3 Applicable Documents

The intent of paragraph 3.3 has been to describe the SC equipment from the standpoint of system, subsystem, and major equipment descriptions. Detailed descriptions and operating procedures are contained in the following publications:

<u>TITLE</u>	<u>PUBLICATION NO.</u>
Microwave Landing System, Ground Subsystem, Small Community Ground Equipment	T16850.36
Microwave Landing System, Ground Electronics, Small Community Ground Equipment	T16850.37

<u>TITLE</u>	<u>PUBLICATION NO.</u>
Microwave Landing System, Antenna Subsystem, Small Community Ground Equipment	T16850.35
Microwave Landing System, Vendor Data, Supplement, Small Community Ground Equipment	TM 081-072
Microwave Landing System, PC Card Test Procedures, Supplement, Small Community Ground Equipment	TM 081-082
Microwave Landing System, Wire Lists, Supplement, Small Community Ground Equipment	TM 081-083

SECTION 4

DETAILED AIRBORNE SYSTEM DESCRIPTION

4.1 INTRODUCTION

This section contains a detailed description of the airborne subsystem hardware. The overall system description was provided in paragraph 2.5 in conjunction with the block diagram of Figure 2-32. Specific end items described include the angle receiver, control panel, auxiliary data display, DME interrogator, DME indicator, antennas, and the angle receiver test set. An occasional reference to Figure 2-32 will indicate the functional interrelationship between the modular avionics system end items.

4.2 ANGLE RECEIVER, BASIC NARROW

4.2.1 Block Diagram Description

The angle receiver processes C-band signals generated by the ground subsystem to derive digital and analog angular data and digital auxiliary data. All data processed by the angle receiver is output by the control panel (paragraph 4.4) and the aux data display (paragraph 4.5).

The signals radiated by the ground subsystem are received by the aircraft antennas. During the preamble (see Figure 2-14), the antenna receiving the strongest signal is selected by the angle receiver, Figure 4-1. This signal is applied through an external antenna switch to the front end consisting of a pre-selector and a mixer. The local oscillator (LO) section of the mixer is driven by the first LO output of the synthesizer. The frequency of the first LO is determined by the channel selected on the control panel. The output of the front end is fed to the first IF amplifier in the RF module. The first IF amplifier, operating at 219.38 MHz, provides gain and automatic gain control, and mixes the signal down to 21.4 MHz. The signal is filtered by a 150 kHz bandpass crystal filter centered at 21.4 MHz and amplified and detected by the log amplifier. The 21.4 MHz is also mixed down to 800 kHz and demodulated to produce DPSK data.

The envelope processor decodes the DPSK data bit pattern to produce the function identification. This programs the digital processor to expect the beams of a particular function to follow and initiates a counter to generate tracking gates around the time of the expected beams. The envelope processor thresholds the beams at 3 dB below their peak amplitudes by delaying the beams and comparing the delayed beam with the peak beam level stored in a peak detector.

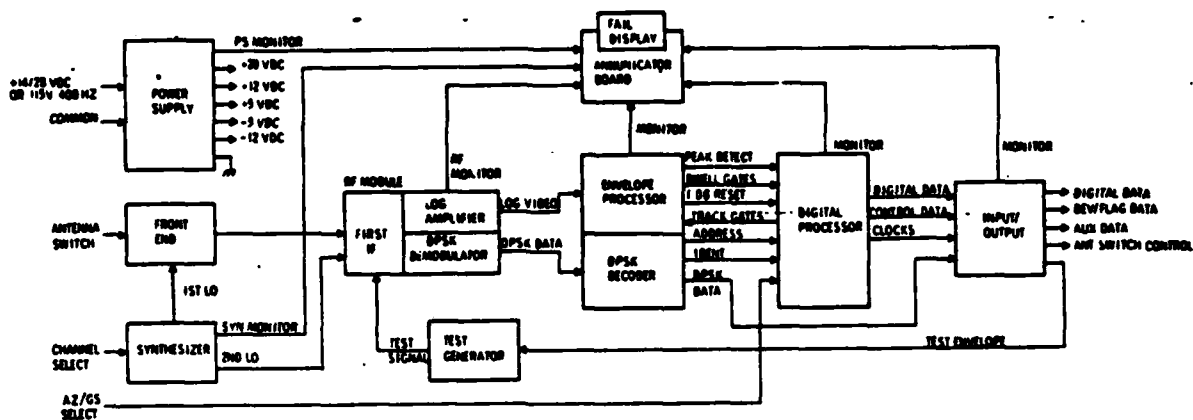


FIGURE 4-1. BASIC ANGLE RECEIVER
BLOCK DIAGRAM

The digital processor measures the time between the TO-FRO beam centroids to compute the angle and deviation data. It also formulates all of the timing functions associated with inputting and outputting of the Basic Narrow angle receiver data.

The Input/Output (I/O) converts and buffers the data from the digital processor to produce a standard ARINC 32-bit word, standard analog CDI deviations and flag signals, and auxiliary data for the Auxiliary Data Display panel. The I/O also produces an envelope test signal for the test generator. The test generator produces a signal to automatically check the angle receiver down to module level.

Self-test of the angle receiver is provided in two ways:

- (a) Power supply, phase lock loop lock-in voltages, and control panel inputs are continuously monitored.
- (b) The manual test switch checks all functions, including the acquisition cycle of the angle receiver and the display and CDI circuitry.

All modules are monitored, and an output for each is applied to an annunciator board connected to a front panel

display which contains an annunciator for each module. A priority system has been established in the event of a multiple failure. Only the annunciator for the module with the highest priority will illuminate.

Each angle receiver module will now be described in detail.

4.2.2 Power Supplies

The angle receiver power supply operates on aircraft bus +14 or +28 V dc or 115 V ac, 400 Hz to provide all power requirements of the unit. Depending upon what voltages are available in the aircraft, an ac or a dc module may be selected to power the angle receiver.

4.2.2.1 DC Power Supply - The dc bus power, Figure 4-2, is filtered by the RFI suppression network. The switching regulator converts either 28 or 14 V dc to 9.0 V dc. The 9.0 V dc is applied to a driver/oscillator circuit that generates a 20 kHz square wave drive signal. The 9.0 V dc is also applied to the primary of a power transformer which provides the necessary output voltages. The excellent synchronization achieved by operating the switching regulator and power transformer at the driver/oscillator frequency greatly reduces frequency modulation and noise problems.

The overload circuit permits the outputs to be shorted indefinitely without damage to the power supply. In the event of power supply failure, the output voltages are maintained below 125 percent of their nominal ratings. The fault monitor provides a warning signal to the annunciator circuit when any malfunction causes the outputs to deviate from their specified limits.

4.2.2.2 AC Power Supply - The aircraft inverter 115 V ac, 400 Hz output is rectified and filtered to 160 V dc. Refer to Figure 4-3. This voltage is regulated at 145 V dc and applied to the dc-to-dc converter. The overload circuit provides protection against overload currents which may be caused by short circuits.

The aircraft 115 V ac is also converted to 12.0 V dc. This 12.0 V dc is the drive and control voltage for a 20 kHz oscillator network which provides the control signal for the dc-to-dc converter. The converter transforms and rectifies the 145 V dc into all required voltages. The power supply fault analysis network monitors the 145 V dc line and the 5.0 V dc

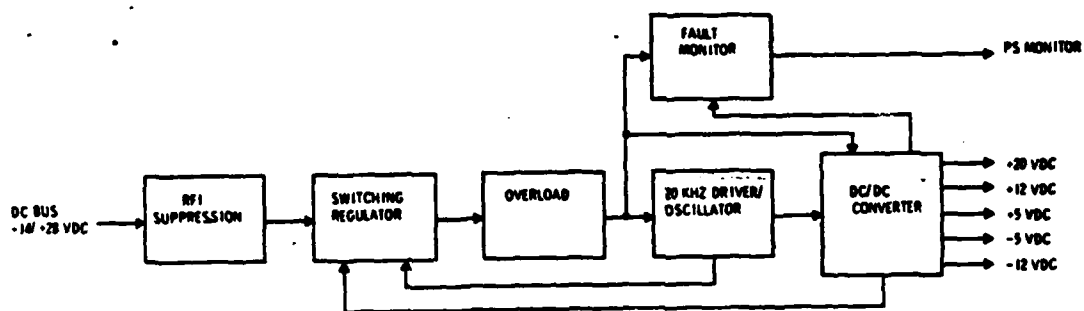


FIGURE 4-2. DC POWER SUPPLY BLOCK DIAGRAM

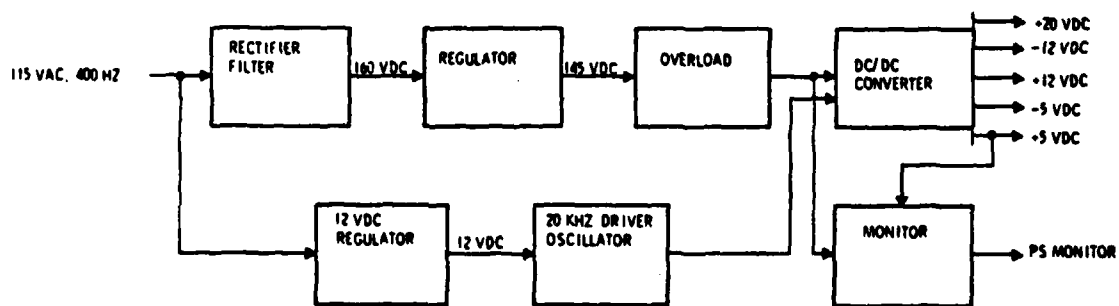


FIGURE 4-3. AC POWER SUPPLY BLOCK DIAGRAM

converter output. The power supply is continuously monitored and has top priority within the annunciator priority encoder.

4.2.3 Front End

The front end module, Figure 4-4, consists of a preselector and a balanced mixer. The C-band signals radiated by the MLS ground stations are received at the aircraft antennas. If the aircraft is equipped with more than one antenna, the angle receiver selects the antenna receiving the strongest signal by means of an external antenna switch. This signal is applied through the preselector to the mixer. The first oscillator of the synthesizer module also applies a signal, the frequency of which is determined by the channel selected, to the mixer. A difference frequency of 219.38 MHz is produced in the mixer and applied to the first IF strip in the RF module.

4.2.4 Frequency Synthesizer

The synthesizer, Figure 4-5, employs a voltage controlled oscillator (VCO) operating in the 1600 MHz range with an output power of 500 to 600 milliwatts. The output is attenuated by an 8 dB pad to provide isolation and is then fed to a step recovery diode frequency tripler. The output of the tripler feeds a stripline bandpass filter to block undesired VCO harmonics. This output drives the oscillator section of the mixer in the front end module. A VCO output of approximately 1.0 mW is monitored.

The signal used to drive the digital control circuitry is derived by mixing a VCO output of approximately 5 mW with a stable standard. The standard is produced by a temperature compensated crystal oscillator (TCXO) and five frequency doublers. The output of the second doubler is used as a second local oscillator injection to the RF module and the output of the fifth multiplier is applied to the mixer. The mixer output is amplified by a triple emitter coupled logic (ECL) line amplifier. This signal is converted to transistor-to-transistor logic (TTL) level and its frequency is divided by sixteen through two dual TTL flip-flops. The flip-flop output is converted to complementary metal oxide silicon (CMOS) logic operating levels and applied to the programmable counters.

The programmable counters further divide the frequency by a factor ranging from 200 for channel 0 to 399 for channel 199. The counter is designed to count in binary coded decimal (BCD) code; therefore, a 2-out-of-5 to BCD interface is required for the channel select input from the control panel. The output of the programmable counter, with the circuit in phase-lock, is 6.25 kHz. The phase of this signal is compared with a 6.25 kHz

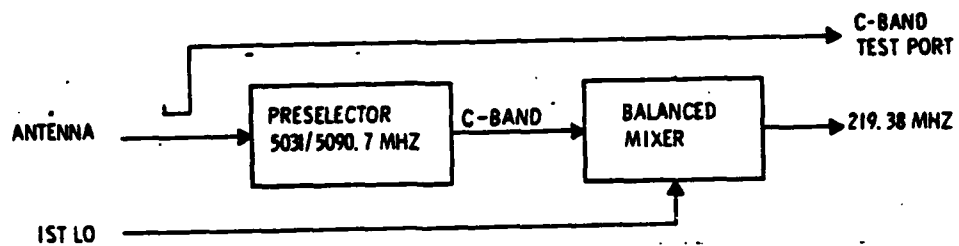


FIGURE 4-4. FRONT END BLOCK DIAGRAM

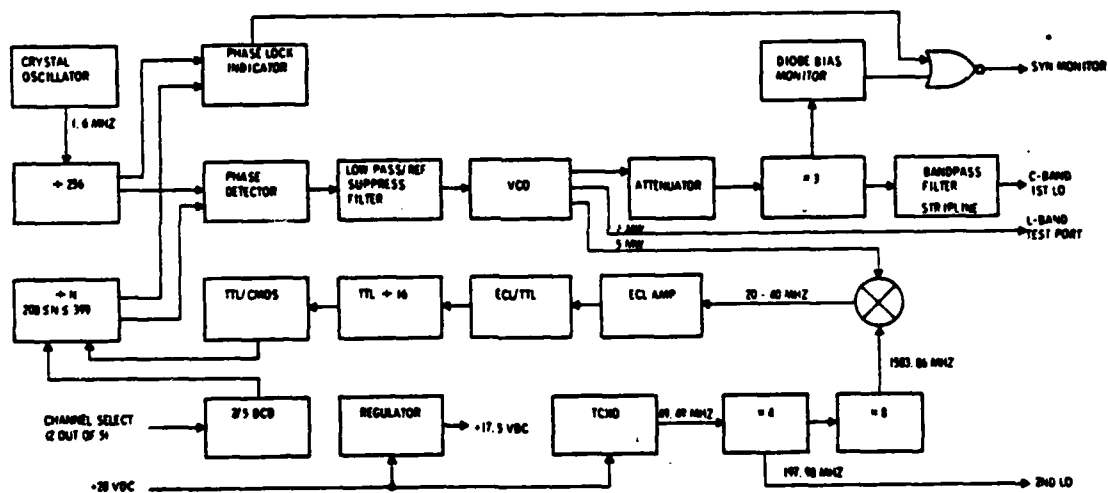


FIGURE 4-5. SYNTHESIZER BLOCK DIAGRAM

reference obtained by dividing the output of a 1.6 MHz crystal oscillator by 256. The phase-lock indicator provides the monitor logic to the annunciator board. The output of the phase detector is applied to a low-pass filter to adjust loop dynamics and to remove any reference frequency components. The filter output is then used as the tuning voltage for the VCO to maintain the circuit in phase-lock.

4.2.5 RF Module

The RF module, Figure 4-6, is composed of three functional circuits; the first IF circuit, the log amplifier, and the DPSK demodulator circuit. The 219.38 MHz input from the front end is amplified, filtered, and mixed with the 197.98 MHz second local oscillator signal from the synthesizer to produce a 21.4 MHz IF signal. The 21.4 MHz IF is applied to the log amplifier where it is filtered and amplified and its amplitude modulation is detected and recovered. The video decoupling network provides the log video output to the envelope processor circuits and to the monitor logic circuit which processes the video for monitor logic to the annunciator board. The video is also applied to a dc amplifier on the IF board where it is conditioned as an automatic gain control (GC) voltage.

The 21.4 MHz output of the log amplifier is applied to the DPSK demodulator where it is mixed with a 20.6 MHz local oscillator signal to produce an 800 kHz signal. This signal is amplified, demodulated by a phase-lock loop circuit, and applied as DPSK data to the DPSK decoder circuit in the Envelope Processor. The DPSK data is also processed and applied to the annunciator circuit as monitor logic utilized in conjunction with the video output.

4.2.6 Envelope Processor

The envelope processor, Figure 4-7, processes the incoming log video and decodes the DPSK data. The envelope processor circuitry generates dwell gates, determined by the incoming log video, that are utilized by the digital processor to determine the angle data in digital form. The DPSK decoder decodes the received DPSK data and provides the digital processor with data concerning the type of angle information being received.

The log video signal applied to the envelope processor is digitized by an analog-to-digital converter. A 3 dB offset is applied to the signal and it is delayed for 213 microseconds. The digitized log video is now compared to a digital signal from the inside tracking gate peak detector. Signals from the peak detectors are determined by tracking the log video input and holding the peak value of the incoming signal. When the delayed log video exceeds the peak detector output, a dwell gate

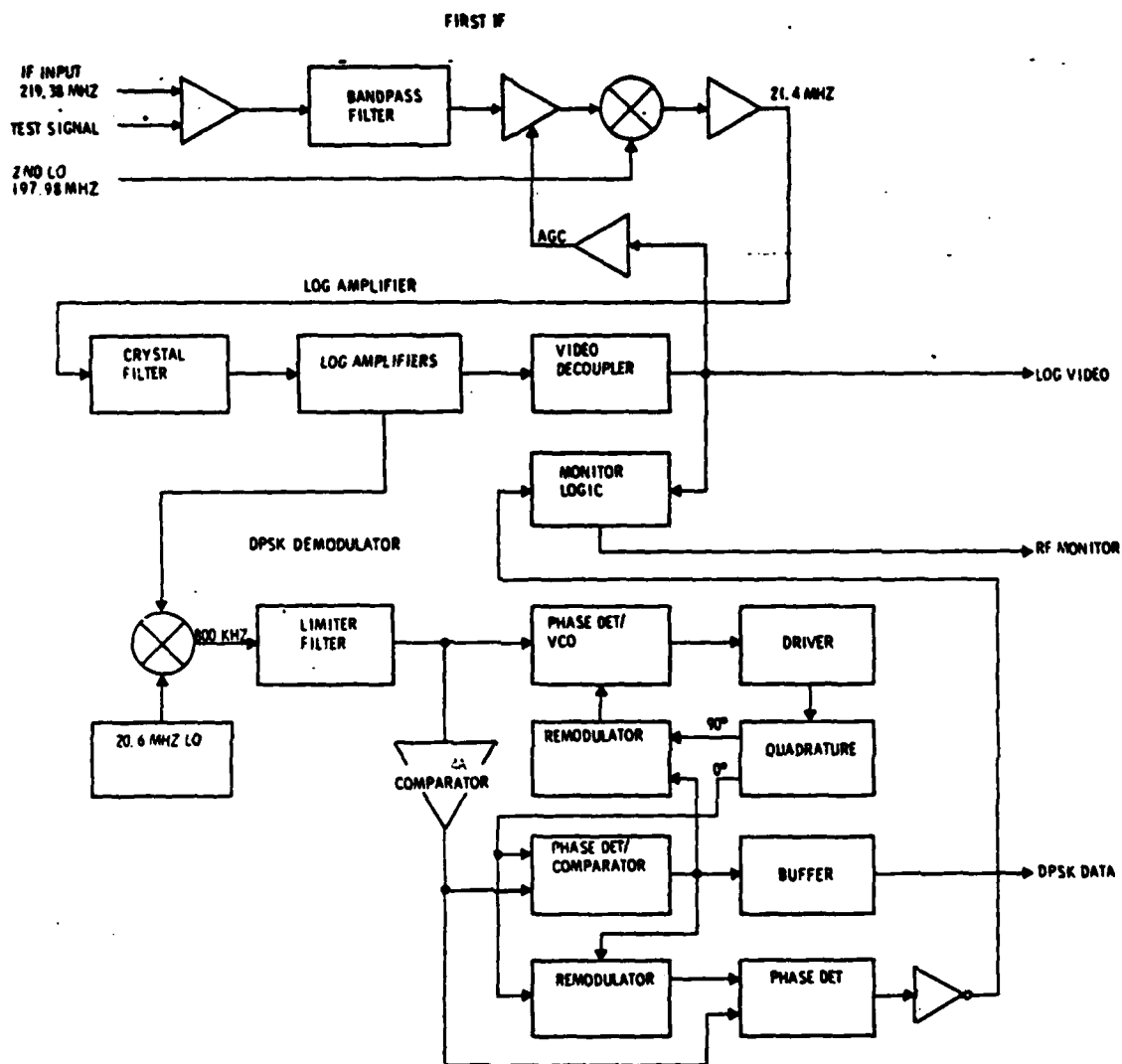


FIGURE 4-6. RF MODULE BLOCK DIAGRAM

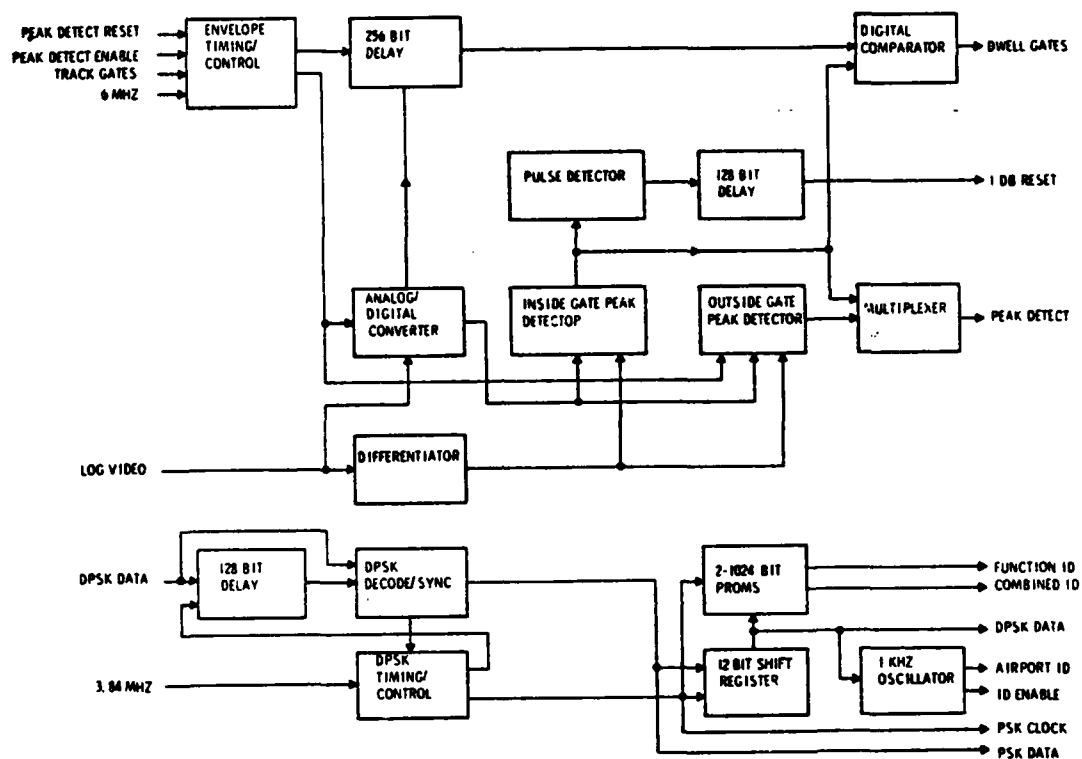


FIGURE 4-7. ENVELOPE PROCESSOR BLOCK DIAGRAM

is generated and transmitted to the digital processor.

The outside gate peak detector is used to detect the peak signal value outside of the tracking gate. Timing and control for the inside and the outside peak detectors are provided by the tracking gates developed in the digital processor. A differentiator network disables the peak detectors when a pulse occurs which is greater than a preset amplitude. This reduces the possibility of an invalid peak value being stored when a noise spike occurs. Both the inside and the outside peak detectors transmit the digital value of their peak signals through a multiplexer to the digital processor.

The DPSK data input is delayed and compared to the undelayed DPSK data. This signal is synchronized to a 15 kHz clock which shifts the DPSK data into a serial to parallel shift register. This signal addresses a programmable read only memory (PROM) that is programmed to identify which function has been received. Function ID's are applied to the digital processor to decode the appropriate function angle data. The airport ID bit in the data message is applied to a 1-kHz oscillator that provides the audio tone. One output of the audio oscillator is supplied to the aircraft communication system and another output is applied to the I/O board to provide an output to the auxiliary data display.

4.2.7 Digital Processor

The digital processor, Figure 4-8, performs the calculations required for system operation. Functions derived from the digital processor include angle computation, tracking gates, filtering, selected glide slope and azimuth sampling and sensitivity, transmission of data to a digital-to-analog converter for CDI operation, and validity (flag) information.

The heart of the digital processor circuitry is the control processor (microprocessor). The control processor is driven by an 18-MHz oscillator and utilizes two random access memories (RAM) and three programmed read only memories (PROM) to perform all of the required mathematical computations. An output of the oscillator is also applied to a divide-by-three circuit to provide a 6 MHz output.

Dwell gates generated from the "TO" and "FRO" sweeps of the ground station scanning beam are applied to the input control circuits which, in turn, start the counters. The counters load dwell gate leading and trailing edge data into the input stacks. This data is buffered and fed to the control processor where the distance between the centroids of the dwell gate is converted to angle data.

Before this angle data is displayed, an initial acquisition period must elapse. During this period, the digital processor performs two sets of checks on the raw data. The frame checks

include measurement of the duration and number of dwell gates, the symmetry of the TO and FRO scans about midscan, and the function repetition rate. When a total of one second worth of acceptable data has been received, the frame flag is set.

The second set of checks is performed by comparing the peak amplitude of the received signal within the tracking gate to the peak amplitude outside the tracking gate on each frame. When the inside peak has exceeded the outside peak for more than one second, the confidence flag is set.

When both the frame and confidence flags are set, the flag on the CDI is lifted, indicating valid data, and the angle data is displayed.

Once this initial acquisition phase is completed, each frame is still validated by being subjected to the frame and confidence checks. The data output of the digital processor will continue to be displayed unless one of three circumstances occurs:

1. The frame error rate exceeds 50 percent of the data rate for more than 1 second.
2. The signal is interrupted for more than 1 second.
3. The confidence check is failed either for a period that exceeds the previous good-confidence-check period (for periods up to 20 seconds) or for a period exceeding 20 seconds.

In the event of one of these circumstances, the output data will be flagged, and the acquisition process will be repeated.

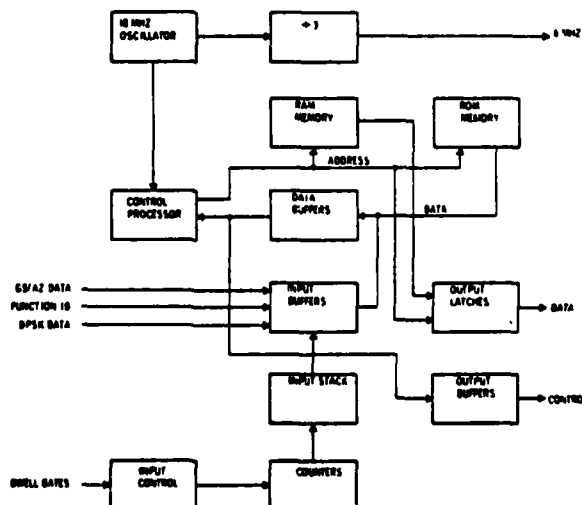


FIGURE 4-8. DIGITAL PROCESSOR BLOCK DIAGRAM

The Function ID and DPSK data inputs determine the function and auxiliary data being calculated at that instant. The GS/AZ data provides the reference signal for the glide slope and azimuth angles selected on the control panel.

The control output provides the control signals for external circuit operation. The data outputs provide signals for CDI and auxiliary data panel information. The data output also includes tracking gates which provide multipath suppression of excessive transients that may appear outside the dwell gate.

4.2.8 Input/Output

The input/output, Figure 4-9, provides the interface between the angle receiver and the other components of the MLS airborne subsystem and other systems. The I/O circuitry is composed of I/O buffers, a video self-test generator, the CDI drive circuit, and a 32-bit word formatter.

The I/O buffers provide the interface to the outside components for control signals generated in the digital processor. The buffers are of three types: tri-state, open collector, and regular totem pole outputs, depending upon the interface requirements.

The video self-test generator produces the DPSK signal format and simulated angle guidance beam signals, automatically as determined by the digital processor and manually by the TEST switch located on the control panel. If the TEST switch is activated, the L/U position produces a left/up indication (AZ needle left, GS needle up) on the CDI and the R/D position causes a right/down deviation.

The CDI drive circuit receives the angle deviation information and full scale range modifier from the digital processor in eight short bursts of four-bit data. The data is latched, converted from digital to analog form, and applied to the CDI. A high range signal provides full scale deviation at ± 2.0 V dc and a low range signal gives full scale deflection at ± 150 mV dc.

The 32-bit word formatter receives the function, angle, and flag information in eight bursts of 4-bit word data from the digital processor. This data is placed in a 32-bit frame and the frame is output at a 15 kHz rate in RZ bipolar signal format.

4.2.9 Test Generator

The test generator, Figure 4-10, produces a 219.38 MHz test signal which is injected into the first IF during self-test. The test generator is composed of a crystal oscillator

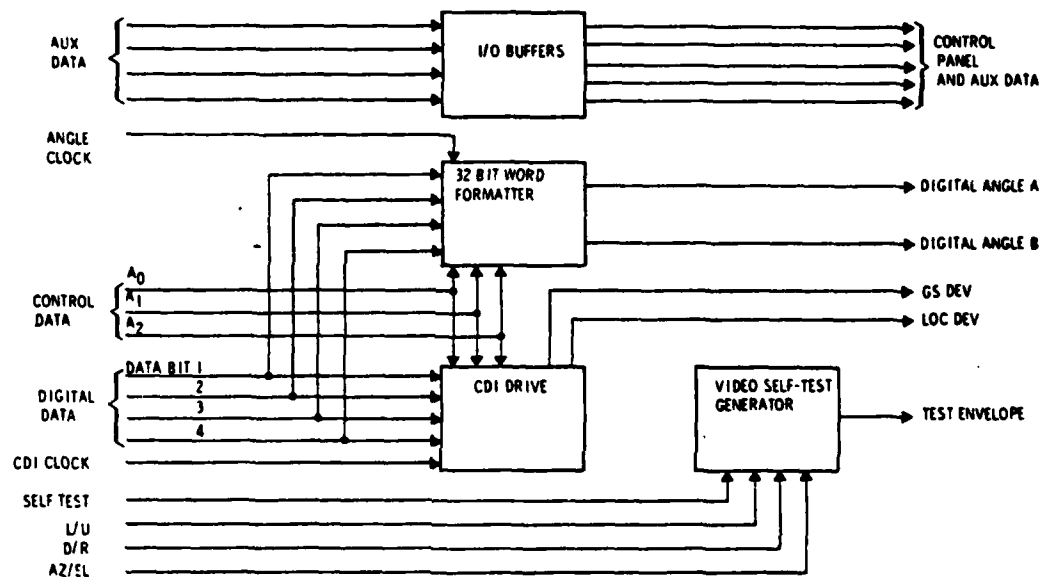


FIGURE 4-9. INPUT/OUTPUT BLOCK DIAGRAM

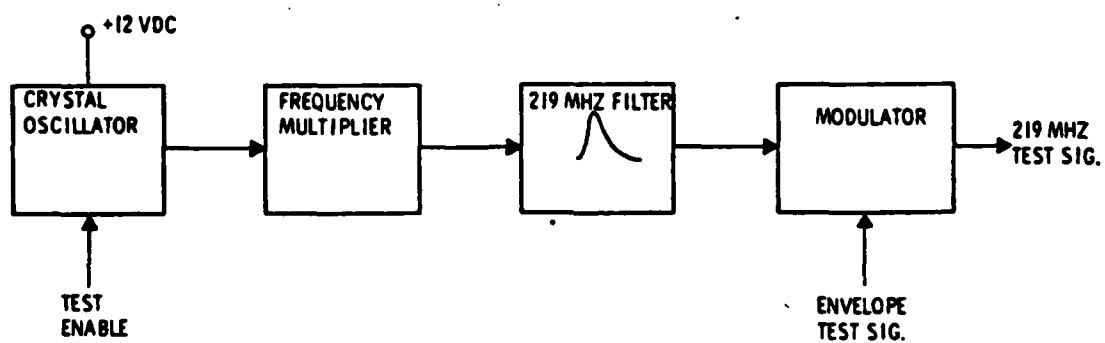


FIGURE 4-10. TEST GENERATOR BLOCK DIAGRAM

driving a frequency multiplier followed by a 219.38 MHz filter and a modulator.

The crystal oscillator provides a stable source at a sub-multiple of the output frequency. The oscillator is switched on only during self-test. The frequency multiplier converts the output of the oscillator up to 219.38 MHz. The filter removes all the undesired harmonics of the oscillator. Unwanted outputs are suppressed by at least 40 dB. The modulator impresses the beam and DPSK information on the 219.38 MHz RF carrier, and the output is fed to a coupler located at the input to the first RF.

4.2.10 Annunciator

The annunciator, Figure 4-11, provides the logic to the angle receiver front panel annunciators for indicating a fault condition. The annunciators isolate a fault to the printed circuit board or module level.

The power supply, synthesizer, and control panel are monitored continuously and with top priority. Some monitor signals are applied to level converter and storage circuits of the annunciator and all monitor signals are applied to the priority encoder. Should a fault occur, the priority encoder is programmed to determine which circuit is responsible for the problem. The fault signal is applied to the BCD to decimal driver which, in turn, supplies the ground return for the appropriate annunciator. All continuously monitored functions display a fault without pressing either test button or being in the test mode.

The TEST switch on the control panel activates one of the timers, dependent upon the switch position, L/U or R/D. The timer initiates the generation of a test envelope in the I/O video self-test circuit, which, in turn, arms the TEST ENABLE via the digital processor. TEST ENABLE unlatches and activates the remaining test circuits. The L/U position of the TEST switch also results in a left deviation of the CDI vertical needle and an up deviation of the horizontal needle. The R/D position produces an equivalent right/down indication on the CDI.

The LAMP switch on the angle receiver front panel provides for a functional test of the annunciator lamps. The front panel TEST initiates a test signal in the TEST L/U timer and results in a left/up indication on the CDI.

4.2.11 Controls/Indicators

The angle receiver front panel control and indicators are illustrated in Figure 4-12 and functionally described in Table 4-1.

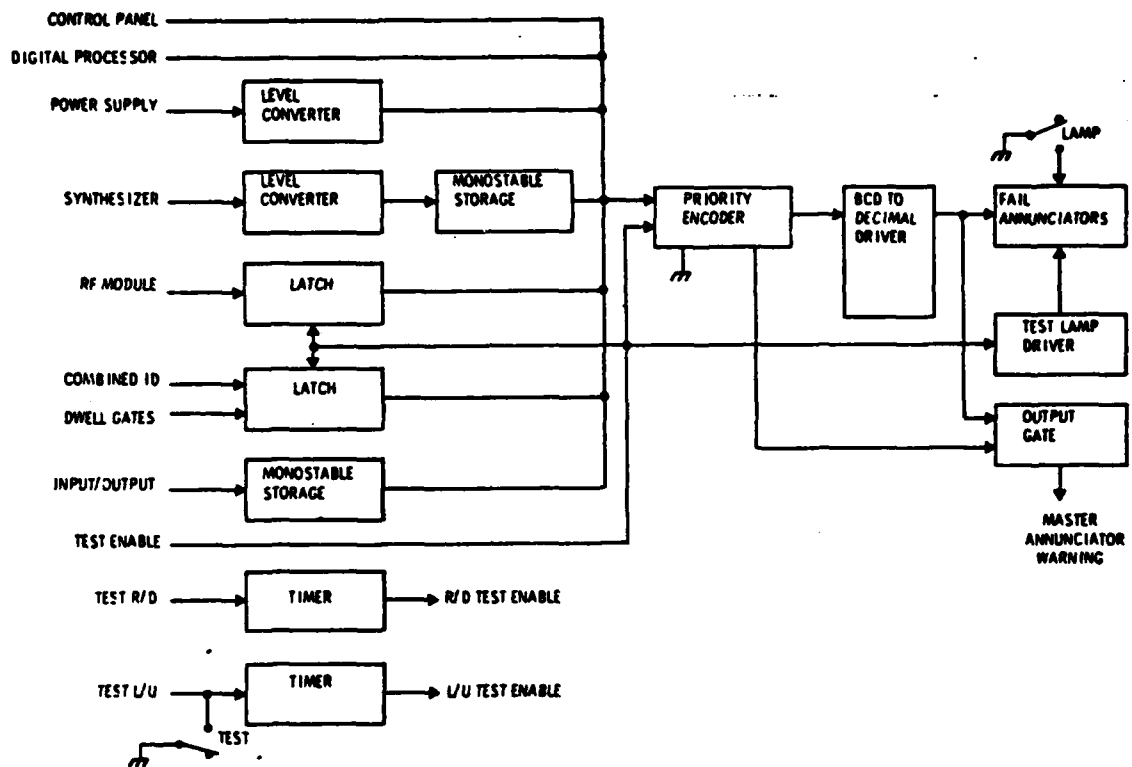


FIGURE 4-11. ANNUNCIATOR BLOCK DIAGRAM

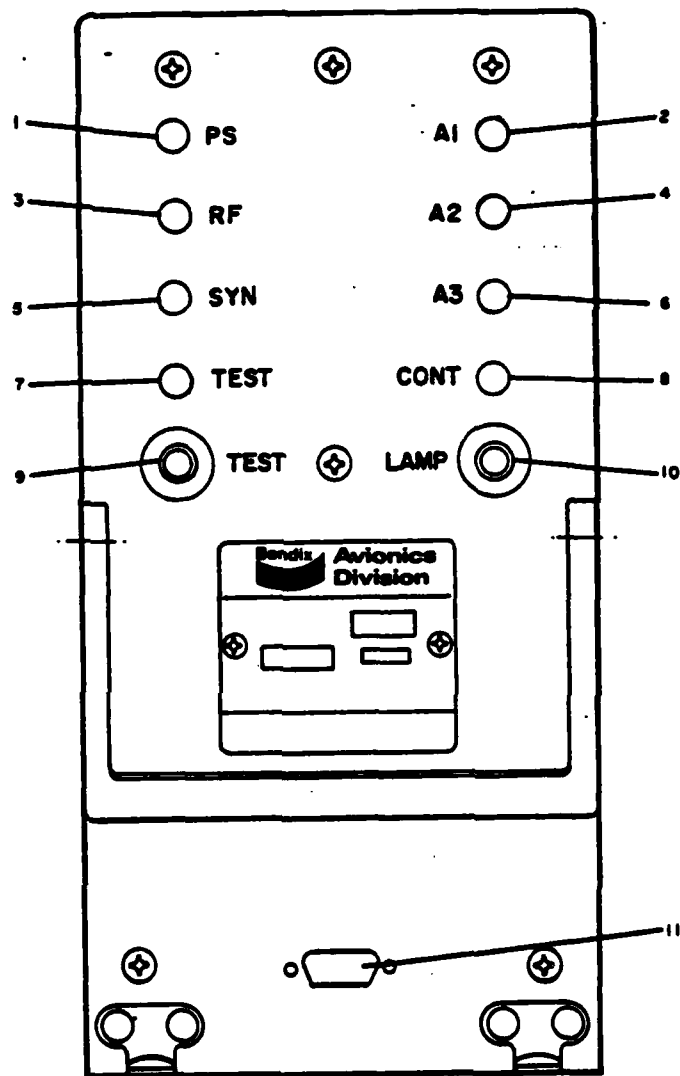


FIGURE 4-12. ANGLE RECEIVER CONTROLS/INDICATORS

TABLE 4-1. ANGLE RECEIVER CONTROLS/INDICATORS

NO.	FUNCTION
1.	Lamp monitoring for power supply section. Lamp turns on when voltages are out of tolerance.
2.	Lamp monitoring for A1 board. Circuit faults turn lamp on. A1 board is the envelope-processor.
3	Lamp monitoring for RF section. Circuit fault turns lamp on. RF section includes IF.
4	Lamp monitoring for A2 board. Circuit faults turn lamp on. A2 board is a digital processor.
5	Lamp monitoring for frequency synthesizer circuits. Circuit faults turn lamp on.
6	Lamp monitoring for A3 board. Circuit faults turn lamp on. A3 board is digital-in/digital-out board.
7	Lamp monitoring for built-in automatic test circuits. Circuit faults turn any other front panel lamp on as well as the TEST lamp.
8	Lamp monitoring for control panel circuit faults.
9	TEST switch to manually initiate the test function for all modules. Associated lamp, when on, indicates circuit faults for one or more boards.
10	LAMP switch checks lamps only. Pressing turns all lamps on.
11	Test jack.

4.3 ANGLE RECEIVER, SMALL COMMUNITY

The mechanical configuration of the Small Community Angle Receiver is shown in Figure 4-13 and is designed for hard or shock mounting. Its physical size is 4.5 inches x 5 inches x 8 inches, while its weight is 10 pounds. The Small Community Angle Receiver modules are identical to the Basic Narrow Angle Receiver modules and are both electrically and mechanically interchangeable. The Small Community Angle Receiver theory of operation is also identical to that of the Basic Narrow Angle Receiver. The two receivers differ only to the extent that, for cost reduction purposes, the Small Community Angle Receiver does not have front panel annunciators and associated circuitry, ARINC case and mounting, RF test generator, and Aux data outputs. Four Small Community angle receivers were delivered to the FAA in Phase III.

4.4 CONTROL PANEL

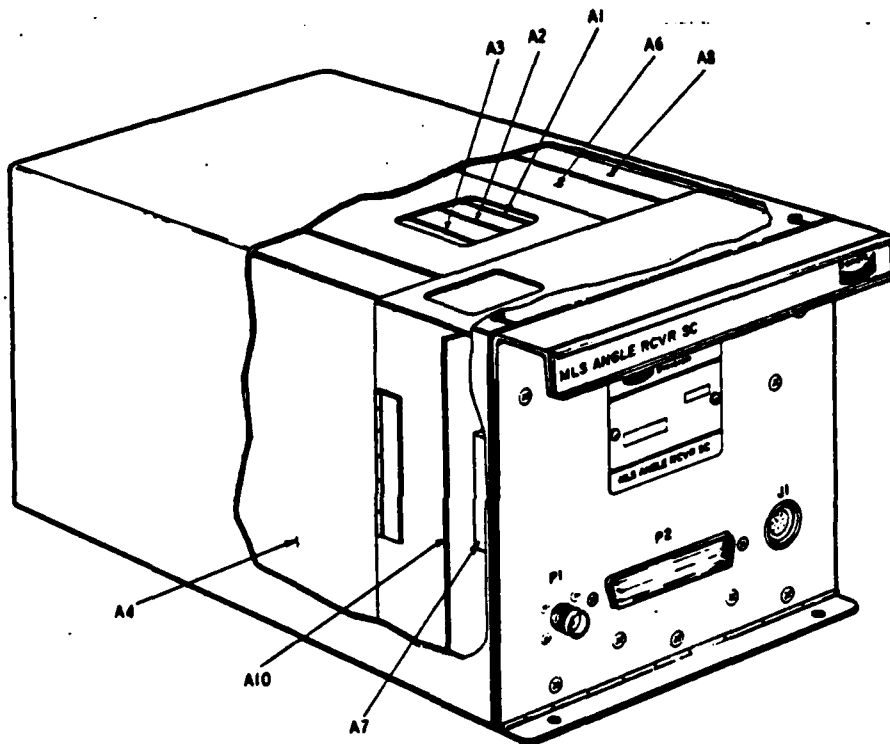
4.4.1 Introduction

The control panel provides for pilot selection of azimuth and elevation heading and MLS channel. Additionally, it contains provisions for system self-test, Morse code volume control, DME mode selection, power on/off, and minimum glide slope warning. The unit requires 3.25 inches x 5.75 inches of cockpit panel space, is 4 inches deep, and weighs approximately 1.5 pounds. The major function selection switches are lighted push-button types and standard edge lighting is incorporated into the panel. The key feature of the control panel is its built-in integrity monitoring.

4.4.2 Control Panel Design

Figure 4-14 illustrates the front panel controls and indicators on the control panel, while Table 4-2 describes their functions.

A functional block diagram of the control panel is shown in Figure 4-15. Here it is seen that the localizer and glide slope switch settings are loaded into a dual encoder with dual independent coded outputs. One set of coded outputs is parallel loaded into a shift register which provides a serially encoded data output to the angle receiver or to the control panel serial to parallel shift register whose outputs are compared to the second independent set of coded outputs from the encoder. If the compared signals are not identical, the integrity monitor alarm is energized. By means of a data transmission direction control, as provided by the inverter, the control panel data



- | | |
|------|--------------------------|
| A1 | Envelope Processor Board |
| A2 | Digital Processor Board |
| A3 | Input/Output Board |
| A4DC | DC Power Supply |
| A6 | Synthesizer Module |
| A7 | Front End Module |
| A8 | RF Module |
| A10 | Interconnect |

FIGURE 4-13. SMALL COMMUNITY ANGLE RECEIVER

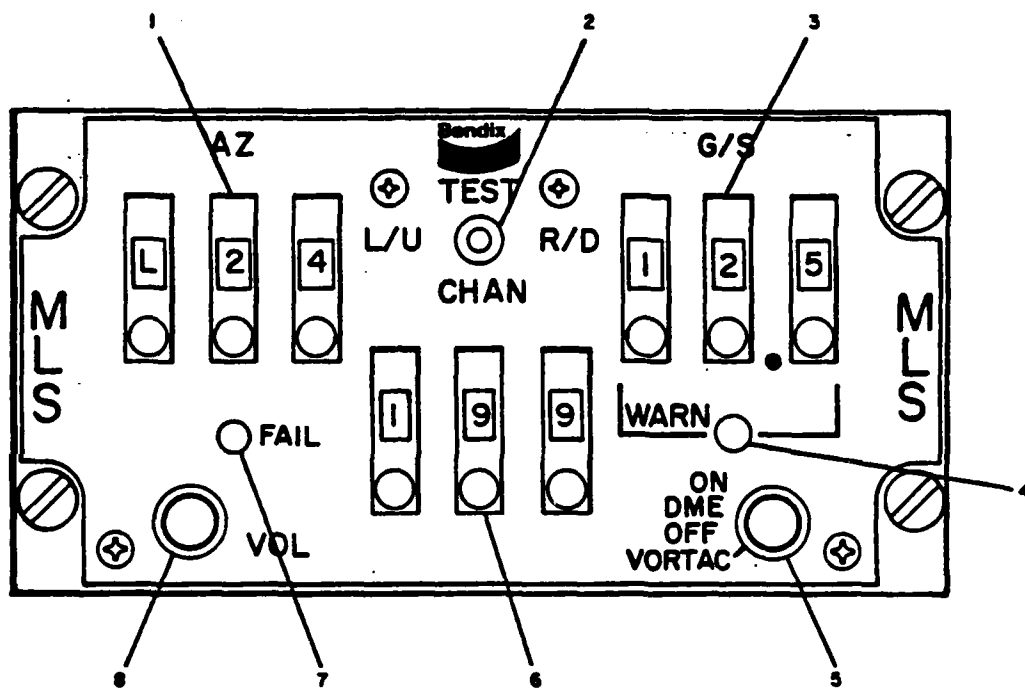
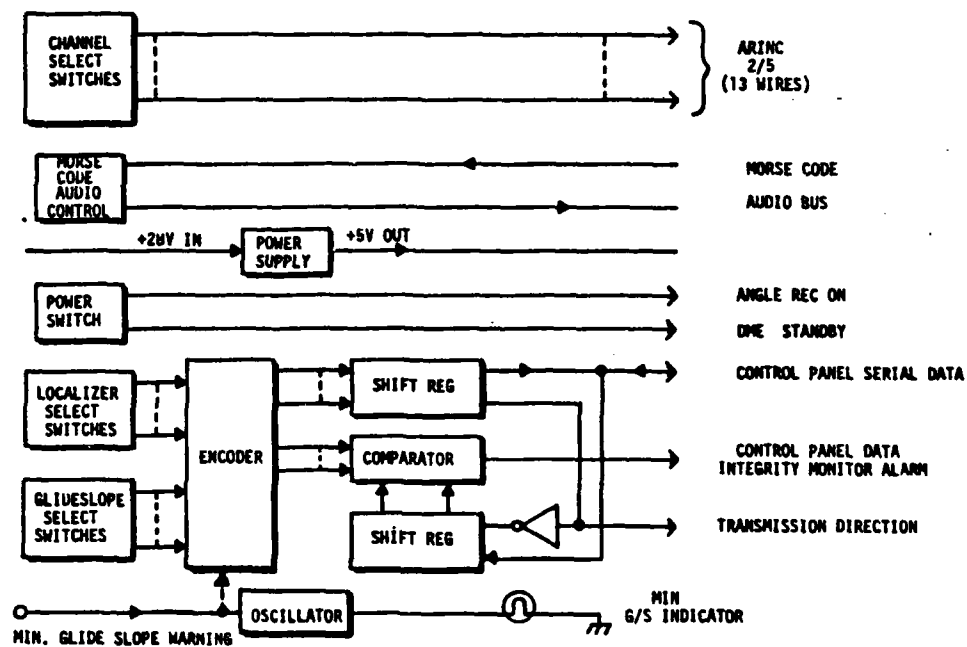


FIGURE 4-14. CONTROL PANEL CONTROLS/INDICATORS

TABLE 4-2. CONTROL PANEL CONTROLS/INDICATORS

NO.	FUNCTION
1	These three push-button digital switches select the azimuth radial used to compute azimuth angle deviation. They range from L00 to L49 and R00 to R49 in one-degree increments. Only angles between L40 and R40 are usable. Angles that exceed this range are converted to either L40 or R40. L/R means left or right.
2	Test junction that generates an L/U (left/up) or R/D (right/down) indicator deflection on the CDI.
3	These three push-button digital switches select the glide slope used to compute elevation angle deviation. They range from 00.0 to 19.5 degrees in increments of 0.5 degrees. Only angles between 2 and 15.5 are usable. Angles exceeding this range are converted to either 2 or 15.5 degrees.
4	If a glide slope is selected that is below the minimum recommended for the landing site, the minimum glide slope indicator will flash at a 1 Hz rate.
5	This switch in VORTAC sets the DME in a standard operating mode. OFF removes all power. DME reserved for future use. ON applies power to angle receiver and transfers the DME from the VORTAC mode to a precision approach MLS mode.
6	These three push-button digital switches select the channel that the MLS angle receiver is on. Their range is from 000-199 dedicated to commercial channels. These are coded in standard 2 of 5 coding.
7	Indicates a failure in the angle receiver.
8	This 500-ohm potentiometer adjusts the audio volume of the Morse code (station identification).



DESIGN FLEXIBILITY

- FIXED GLIDESLOPE DESIGN CAN BE PROVIDED
 - IF FIXED IS LESS THAN MIN. MIN IS USED
- SELECTED GLIDESLOPE CAN BE PRESET AND MECHANICALLY LOCKED
- CONTROL/DISPLAY PANELS CAN BE INTEGRATED TO CONSERVE PANEL SPACE

FIGURE 4-15. CONTROL PANEL BLOCK DIAGRAM

stored in the angle receiver is loaded into the control panel serial-to-parallel shift register where, again, a comparison is made to the second independent set of coded outputs from the encoder.

Additional circuits contained within the control panel include the Morse code audio control and interface with the aircraft audio system. Also, when the selected glide slope is less than the minimum selectable glide slope for the given facility, a glide slope warning signal from the angle receiver processor energizes a low frequency oscillator within the control panel to control a front panel lamp which will alert the pilot.

4.5 AUXILIARY DATA DISPLAY

The auxiliary display is shown in Figure 4-16. Table 4-3 identifies the functions of the controls and displays.

Auxiliary data display inputs include raw 28 VDC for its integral power supply, digital angle data from which azimuth heading is extracted, the aux data clock, and the 64-bit aux data word which contains facility identification, facility category, minimum selectable glide slope, runway identification and runway condition.

The auxiliary data circuitry receives the data and checks it for validity, establishes interval timing to provide for data decoding, provides for switch selectable display of the desired data item, and multiplexes the proper data onto the four character display via display encoder/driver circuitry. Invalid or flagged data is represented by a series of four dashes in the display. For effective preflight testing of the aux data display, when the display is set to select azimuth, the display will indicate the internal angle receiver test azimuth angle during the system manual test made after the angle receiver has completed its acquisition and validation cycle.

4.6 DME INTERROGATOR

4.6.1 Introduction

The DME interrogator design is in general conformance with ARINC 568 and 582 and exhibits a ranging accuracy of ± 76 feet (2σ) including multipath effects in the MLS mode versus a typical ranging accuracy of ± 600 feet (2σ) for conventional ICAO Annex 10N, L-Band DME Interrogators. This interrogator is the airborne terminal of the total DME subsystem whose system ranging accuracy is ± 100 feet (2σ) including the effects of multipath.

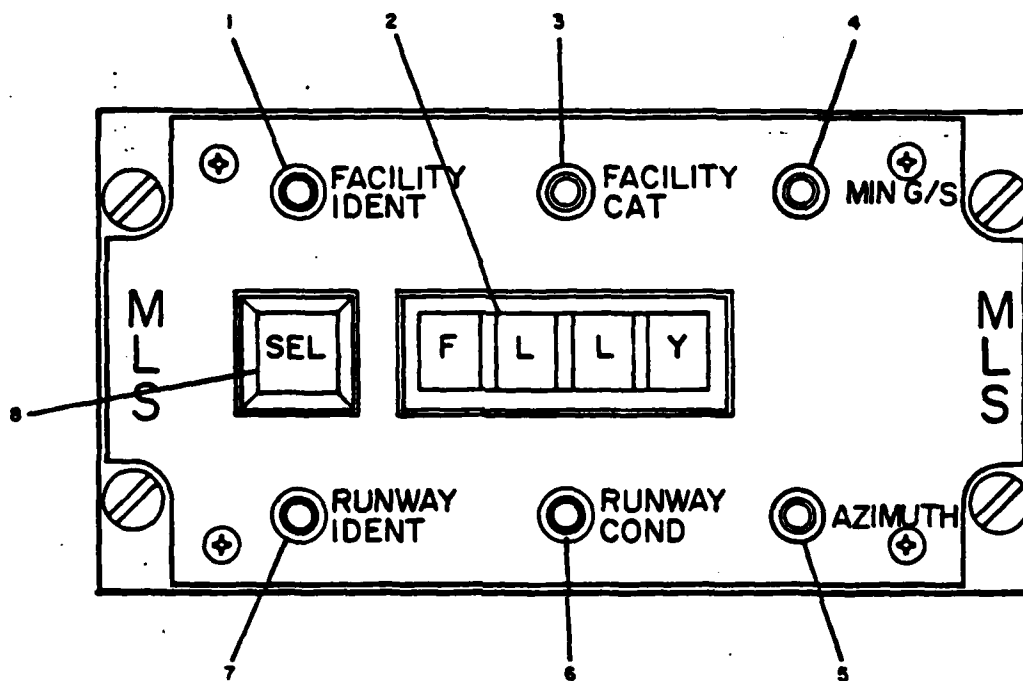


FIGURE 4-16. AUX DATA CONTROLS/INDICATORS

TABLE 4-3. AUX DATA CONTROLS/INDICATORS

NO.	FUNCTION
1	When pressed selects the FACILITY IDENT function for display when SEL is pressed. The display appears in the framed area to the right of SEL (item 2). The display is a three-letter combination such as IDL, FTL, etc..
2	The display area for the various selected functions. The display may be a combination of letters and/or numbers when pressing SEL. Display disappears after a few seconds or after another function is selected.
3	When pressed, selects the FACILITY CAT (category) function for display when SEL is pressed. Display is I, II or III. These categories relate to weather-handling capabilities of the ground facility. The using aircraft must have the proper equipment to comply with the conditions existing.
4	When pressed, selects the MIN/GS (minimum glide slope) function available at that facility when SEL is pressed. Display will be in degrees. First digit can be either 0 or 1, second digit 0 to 9, and the third digit .0 or .5.
5	When pressed, selects AZIMUTH function for display when SEL is pressed. The display is initially L or R followed by two digits. This figure is the number of degrees the aircraft is L (left) or R (right) of the runway centerline. As aircraft approaches the centerline, this reading decreases numerically to 00.
6	When pressed, selects the RUNWAY COND (condition) function for display when SEL is pressed. Display is WET, ICE, etc.
7	When pressed, selects the RUNWAY IDENT function for display when SEL is pressed. Display is a two-digit runway heading with L (left) or R (right) direction indicator such as 15L or 15R and 33L or 33R, etc.
8	When pressed, selects each of the above functions for display.

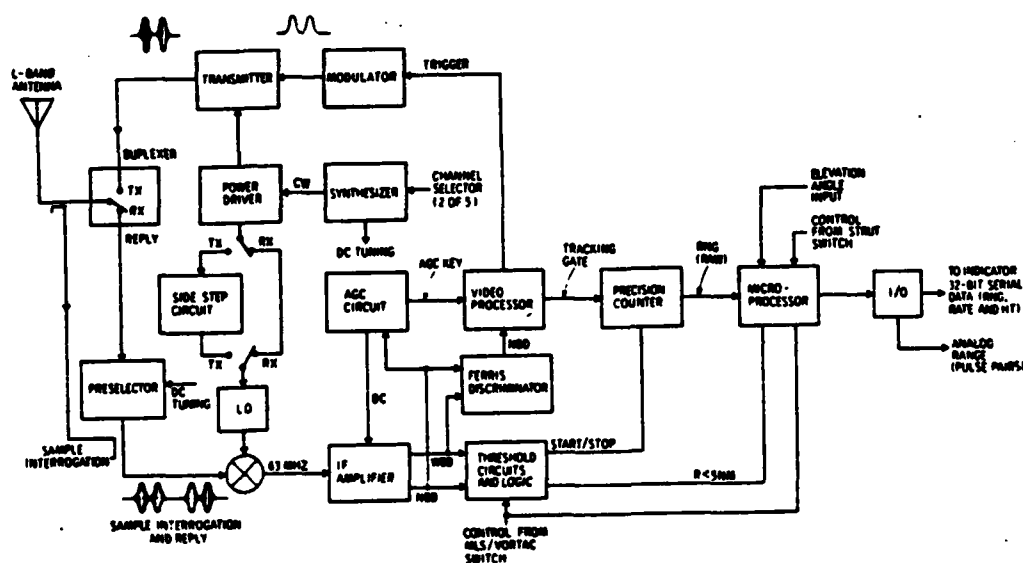
Several months after Phase III was initiated, a decision was made to implement a precision DME system in lieu of a standard commercial system as was originally required. Because of the resulting time constraint on new precision DME development, rather than begin a new MLS precision DME interrogator design from scratch, it was decided to modify the existing Bendix commercial DME interrogator, Model 2030. Several DME 2030 modules have been modified, where necessary, and combined with several new modules which were specifically designed to satisfy the more stringent MLS requirements. The entire unit was packaged into a short 1/2-ATR case to be compatible with installation in aircraft wired for a standard ARINC 568-4 type airline DME interrogator.

4.6.2 DME Subsystem Description

A block diagram of the precision DME interrogator is shown in Figure 4-17. When the interrogator is energized, the microprocessor and control logic generate a repetitive pattern of properly spaced pulse pairs which are acted upon by the modulator to modulate the transmitter which generates the RF interrogation pulses. The RF carrier frequency source is the synthesizer whose frequency is established by the switch settings of the frequency control panel. The synthesizer RF output is amplified by the driver, which serves as the transmitter exciter. During the transmit mode, the duplexer routes the transmitter output pulses to the antenna. A sample of the transmitter output is coupled to the receiver mixer input to form a T_o loop, whose function is to start the range counter in a manner which allows the interrogator pulse pairs and the received reply pulse pairs to traverse the same receiver circuitry for delay stabilization. In order to convert the transmitter "START" pulse pair to 63 MHz, the L.O. has to be different in the transmit mode by 63 MHz. This is accomplished by the side-step circuit.

The ground transponder receives the interrogation pulses and, after a fixed delay, retransmits a pulse pair to the interrogator. The reply carrier frequency always differs from the interrogation frequency by 63 MHz.

The reply pulse pair from the ground transponder passes through the interrogator duplexer, which is preset to the receive mode. A voltage tuned preselector provides the necessary image rejection. The received reply pulse pairs are then converted to the IF frequency (63 MHz), amplified, detected, and, after thresholding and proper decoding, stop the precision Counter. The elapsed time between transmission of the interrogation pulse pair and reception of the transponder pulse pair is converted directly to distance.



NBD = Narrow Band Detector

WBD = Wide Band Detector

FIGURE 4-17. PRECISION DME INTERROGATOR
BLOCK DIAGRAM

The receiver has a wideband (3.5 MHz) and a narrow band (0.35 MHz) output. The wideband channel is used during the precision MLS mode whenever the distance to the GPIIP is less than 5 NM. This wideband channel provides the fidelity required to prevent distortion of the leading edge of the first pulses of the interrogation and reply pulse pairs, which are used for measuring range. In the VORTAC mode, the interrogator uses the narrow band IF output (0.35 MHz) since it gives better signal to noise ratio and, therefore, better long range performance. The resulting leading edge distortions are immaterial because of the reduced VORTAC accuracy requirements (600 feet).

The L-band DME system employs channels at 1 MHz intervals. Without special precautions, adjacent channels would cause interference in the MLS mode with 3.5 MHz bandwidth. The Ferris discriminator eliminates such adjacent channel problems which could cause false readings. The Ferris discriminator essentially compares the energy in the wideband channel with that in the narrow band channel, which is centered on the channel frequency. The comparator generates an enabling gate only for "ON Channel" replies.

In addition to the reply pulse pairs, the ground transponder also transmits squitter pulse pairs which are transmitted randomly at an average rate of 2700 P.P.S. The tracking gate from the LSI circuit rejects most of these squitter pulses since they are not synchronized with the interrogation. The squitter pulses are very useful for controlling the gain of the interrogator receiver (AGC). Since the squitter pulses are received at a much higher frequency (2700 pps) than the reply pulses (30 or 15 pps), they provide advanced information regarding the amplitude of the replies. The video output of the receiver can, therefore, be held constant over the dynamic range as an aid to reducing ranging error.

The "raw" range information from the precision counter is filtered in the microprocessor which also computes range rate and height from elevation angle. The microprocessor also converts the parallel binary digital data to serial BCD data suitable for display on the indicator. Also provided is a pulse pair whose spacing is proportional to distance. This output is required for RNAV equipment which allows curved path approaches.

The original DME 2030 interrogator used an LSI video processor circuit which performs practically all decoding, encoding, and processing functions required for measuring range. Unfortunately, the resolution of this LSI ranging circuit was inadequate for the precision MLS ranging purposes because of its low clock frequency (1.6 MHz). It was, therefore, decided

to derive only a noncritical tracking gate from this LSI circuit for the feasibility model. A supplemental precision counter with a 20 MHz clock provides adequate resolution for the feasibility model interrogator.

Distance, and therefore height measurements, during the critical landing phase can be adversely affected by multipath signals. In order to reduce these effects, four basic requirements must be met, namely:

- 1) The interrogation and reply pulse timing must be measured to the first pulse of the pulse pair, which is generally less distorted than the second one.
- 2) The time measurements must be made as early as possible on the leading edge of the pulses since multipath signals always arrive after the direct signal.
- 3) The portion of the leading edge where the measurement is made must be as steep as possible to prevent distortion by multipath signals. A COS leading edge was, therefore, selected for MLS instead of the COS^2 wave-shape (VORTAC).
- 4) The threshold must not be referenced to the peak of the pulse since this peak is also subject to the multipath distortions.

Table 4-4 briefly summarizes the design parameters of the interrogator, whereas Table 2-31 lists the major DME interrogator specifications.

4.6.3 Modifications To Bendix Model 2030 DME Interrogator

A summary of required design modifications to the Bendix Model 2030 DME Interrogator is provided in Table 4-5. Additional details are available in the MLS DME Interrogator technical manuals.

4.7 DME INDICATOR

4.7.1 Introduction

A new DME indicator was designed during Phase III to permit high precision display of the range, range rate and height outputs generated within the MLS DME interrogator. Figure 4-18 represents a front panel view of the indicator which requires only 1-1/2 inch x 3-1/4 inch cockpit panel space. Table 4-6 identifies the various functions indicated on the front panel.

TABLE 4-4. PRECISION L-BAND DME INTERROGATOR
PARAMETERS (FEASIBILITY MODEL)

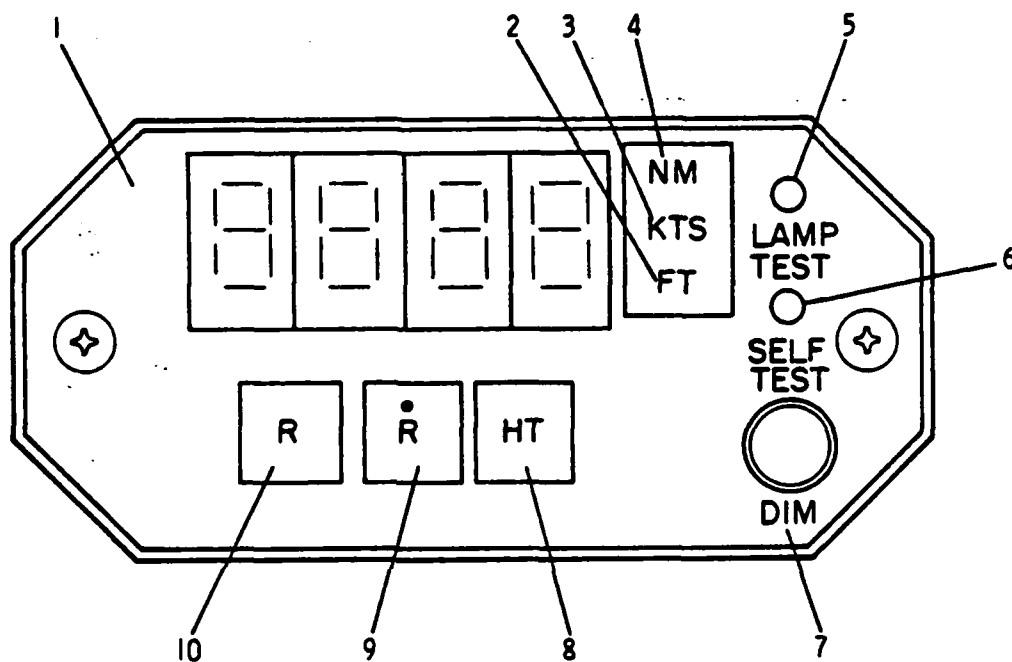
PARAMETER		VORTAC MODE	MLS MODE	
			0 - 5 NM	5 - 30 NM
VIDEO BANDWIDTH (MHz)		0.5	3.5	0.5
VIDEO THRESHOLD		-6 dB	0.03 μ sec (VARIABLE)	-6 dB
SEARCH RANGE (NM)		0-200	0 - 30	
TRACK PRF (PPS)		15	30	15
SEARCH PRF (PPS)		150	300	150
MEMORY (SEC)		10	1	10
REFERENCE POINT (NOTE 1)	INDICATOR	XPDR	GPIP	
	RNAV OUTPUT		XPDR	
α/β CONSTANTS (MICROPROCESSOR)		α_1/β_1	α_2/β_2	α_1/β_1
CHANNEL SELECTOR		EXISTING VOR CONTROL PANEL		
NAVIGATION MODE SWITCH		VORTAC	MLS	

NOTES:

- 1) Whenever the aircraft is on the ground (strut switch closed), the DME reference point is the transponder. The indicator displays three digits after the decimal point. Height display is flagged.

TABLE 4-5. INTERROGATOR DESIGN
MODIFICATION SUMMARY

- HIGH SPEED PRECISION DIGITAL RANGING CIRCUITS (MSI) FOR GREATER PRECISION RANGING MEASUREMENT
- NARROW/WIDE BANDWIDTHS (3.5/.35 MHZ) FOR MLS MODE/NORMAL ENROUTE DME MODE
- DUAL MODE FERRIS DISCRIMINATOR FOR ADJACENT CHANNEL REJECTION
- TWO LEVEL THRESHOLD (-6 dB FOR ENROUTE, DELAY AND COMPARE TECHNIQUE FOR MLS MODE)
- SAMPLED TRANSMITTER PULSE PAIR STARTS RANGE COUNTER FOR INTERNAL DELAY STABILIZATION
- FIRST PULSE TIMING TO MINIMIZE MULTIPATH EFFECTS
- \cos/\cos^2 XMTR FIRST PULSE WAVESHAPE FOR FASTER RISE TIME
- \cos^2 XMTR SECOND PULSE WAVESHAPE FOR CODE IDENTIFICATION
- LSI TRACKER TO MINIMIZE PARTS COUNT
- ECHO LOCK PREVENTION CIRCUIT (LSI) TO PREVENT TRACKING ON MULTIPATH
- DUAL MEMORY (10 SEC. FOR NORMAL MODE, 1 SEC. FOR MLS MODE)
- MICROPROCESSOR (INTEL 8080) FOR EASE OF LOGIC IMPLEMENTATION
- ALPHA-BETA TRACKER FOR TIMELY DATA PRECISION
- TRIPLE MODE INDICATOR (R, \dot{R} , H) TO PERMIT USE OF PRECISION DME DATA
- MANUAL SELF TEST
- ARINC COMPATIBILITY (WIRING, CONNECTORS, FORM FACTOR) FOR EASE OF INSTALLATION
- HEIGHT COMPUTATION ON CENTERLINE, TERRAIN INDEPENDENT



NOTE: Controls are defined in Table 4-6.

FIGURE 4-18. DME INDICATOR CONTROLS/INDICATORS

TABLE 4-6. DME INDICATOR CONTROLS/INDICATORS

NO.	FUNCTION
1.	Display area for all functions.
2	When illuminated, NM indicates that display reading is in nautical miles. This is range or distance to the ground station.
3	When illuminated, KTS indicates that display is in knots per hours. This is aircraft speed (DME derived).
4	When illuminated, FT indicates that display is in feet. This is aircraft height in feet over the runway.
5	When pressed, all lamps are illuminated. The number 1 area displays 8888.
6	When pressed, the number 1 area will display either of the following, depending upon the operating mode. <div> <div>VORTAC MODE</div> <div>MLS MODE</div> </div> <div> <div>Blank for one sec.</div> <div>Blank for one sec.</div> <div>----for one sec.</div> <div>----for one sec.</div> <div>0000 for one sec.</div> <div>3,000 NM for one sec.</div> <div>120 KTS for one sec.</div> <div>100 FT for one sec.</div> </div>
7	DIM control for lamp illumination level.
8	When pressed, selects HT (height) readout in feet.
9	When pressed, selects R (range rate) readout in knots per hours.
10	When pressed, selects R (range) readout in nautical miles.

The indicator accepts the serial data, clock and word sync from the interrogator. The Range (R), Range Rate (R), and Altitude (HT) buttons on the front panel select which data label is to be accepted and displays that data. Range is displayed in nautical miles in 0.1 nm increments, except during "on runway" computations and self-test, at which time the range is displayed in 0.001 nm increments. Range rate is displayed in whole knots and height is displayed in whole feet. Once the data has been received, the input is inhibited for 500 milliseconds. This produces an update rate of approximately 2 per second.

When non-computed data is received, the display is dashed. Failure to receive valid clock, data, word sync, flag, or power will result in a blanked display and the status output will go low.

4.7.2 Circuit Design

A circuit block diagram of the DME indicator is illustrated in Figure 4-19. The indicator consists of three sections: the input, the control, and the display driver.

The Input provides for data buffering/level shifting of the data, sync and clock inputs from the interrogator. The sync and clock inputs are combined in the sync generator to enable label decoding at the proper time and to generate an enable gate which controls the operation of loading data bits into the digital shift registers in the display driver. The data input format is per ARINC 568, which consists of a 32-bit word, where the first eight bits identify the label, bits 9 through 16 are not used, bits 17 through 30 are BCD data bits, while bits 31 and 32 are special coding labels. The input also contains a fail/monitor circuit and a 5 VDC regulator.

The control circuit provides for label decoding based on front panel switch selections, for generation of the data load clock, for dash, decimal point, and indicator blanking logic and for timing to establish the data update rate and data blanking.

The display drive contains two 8-bit shift registers which feed four BCD to seven segment decoders which drive the front panel data indicators. The most significant data indicator is limited to a maximum numeric of three established by bits 29 and 30. Table 4-7 further defines the indicator display formats.

4.8 ANTENNAS

Antennas for the C-band angle receiver were supplied in both the horn and the stub types. Figure 4-20 illustrates the

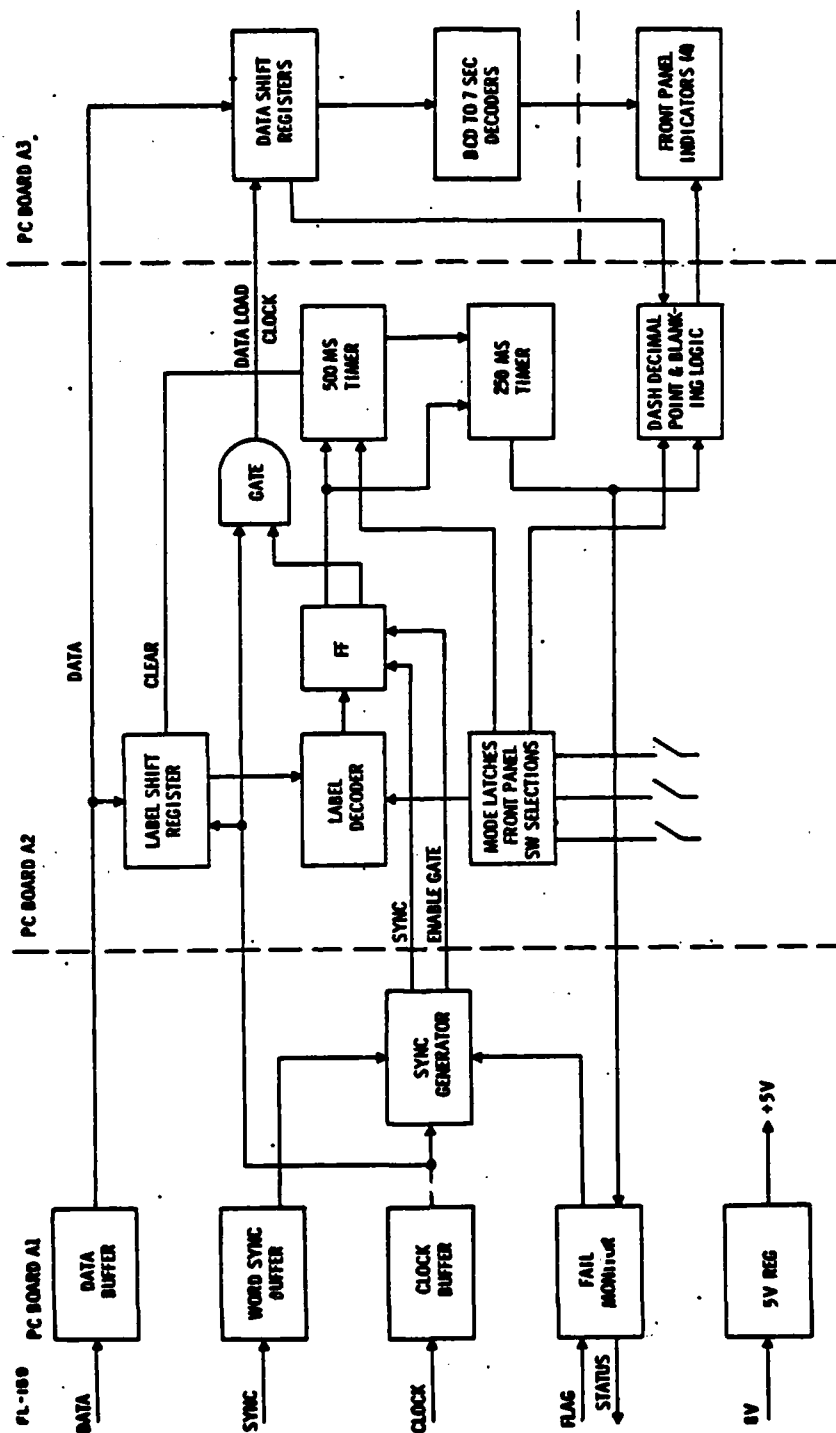


FIGURE 4-19. DME INDICATOR BLOCK DIAGRAM

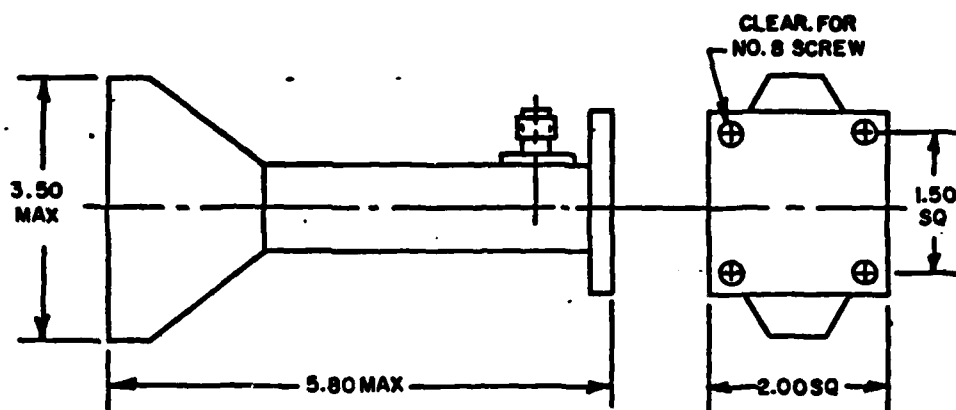
TABLE 4-7. INDICATOR DISPLAY FORMAT ACCORDING TO
FUNCTION SELECTED FOR DIFFERENT CONDITIONS

CONDITION	RANGE (N.M.)	RANGE RATE (KTS.)	ALTITUDE (FT.)
Search Mode	-	-	-
Test Mode Phase III (MLS Selected)	0.000 + .004	120	100
Test Mode Phase III (MLS Not Selected)	0.000 + .004	120	-
On Ground	T.TTT	RRRR	-
Airborne, MLS Mode, Range* <5 N.M. (Precison Mode)	GGG.G**	RRRR	HHHH
Airborne, MLS Mode, 5 N.M. < Range < 30 N.M.	GGG.G	RRRR	-
Airborne, MLS Mode, Range < 30 N.M.	-	-	-
Airborne, Not In MLS Mode	TTT.T	RRRR	-

- NOTES: (1) Display is blank if flag line to indicator is less than 9V.
- (2) Display is blank if serial data not updated for 0.75 sec.
- (3) T.TTT is range to transponder
GGG.G is range to GPIIP
HHHH is height
RRRR is range rate

* All references are to values as displayed.

**Display is dashes if range to GPIIP < 0 N.M.



Specifications

Frequency	5.0-5.25 GHz
VSWR	<2.0:1
Gain	≥ 5 dBi
Polarization	Vertical
Radiation Patterns	
Azimuth	$\geq 180^\circ$ @ 6 dB BW
Elevation	$\approx 60^\circ$ @ 6 dB BW
Front to Back Ratio	≥ 10 dB
Weight	4.5 Oz. Max.
Connector	TNC Jack

FIGURE 4-20. AVIONICS C-BAND HORN

horn type antenna with applicable specifications, while Figure 4-21 illustrates the stub type antenna with its applicable specifications.

The L-band-antenna supplied with the DME interrogator is an omnidirectional quarter-wave dipole as indicated in Figure 4-22.

All antennas are vertically polarized.

4.9 ANGLE RECEIVER TEST SET

A relatively compact and versatile angle receiver test set was developed and delivered during Phase III. The MLS Angle Receiver Test Set is a self-contained unit designed to generate the full range of TRSB signals required to completely test the functions/capabilities of all MLS angle receiver configurations, including the Small Community and the Basic Narrow configurations. Test set output signals contain the required MLS TRSB signal format which consists of a DPSK* modulated/amplitude modulated carrier frequency containing the same information that would be generated by the ground subsystem. The test set has its own internal frequency reference and provides full channel coverage at C-band, plus outputs for testing at the angle receiver IF passband. Front panel controls and rear panel connectors provide for wide range flexibility in the selection of the various functions contained in the MLS signal format. The test set is portable and may be used on the bench or carried to the aircraft. Table 4-8 summarizes the major specifications of the test set. The system description in block diagram form follows and is keyed to Figure 4-23.

The master timing generator contains a free running oscillator that is counted down to produce a signal that simulates the ground station omni pulse. The generated pulse is buffered, brought to a rear panel output connector for use as a sync, and further used to trigger the DPSK encoder. A combined omni pulse triggers an interval counter that feeds a bank of comparators. Depending upon the function ID and the settings on the front panel switches, the comparator's output is two pairs of pulses symmetrically spaced around the function's point of symmetry. The first pulse pair triggers a beam shaper to form the main beams and the second pair triggers another beam shaper to form the multipath beams. The DPSK message, main beams, and multipath beams (reflections) are combined to form the passband signal of the angle receiver. This signal is mixed with a sine wave to produce the angle receiver IF. The IF is then mixed with a C-band carrier to produce the MLS signal that would be seen by an airborne angle receiver.

*Differential Phase Shift Keying

SPECIFICATIONS

- FREQUENCY RANGE 5.0 to 5.25 GHz
- GAIN ≥ 5 dBi
- VSWR $\leq 2 : 1$
- IMPEDANCE 50 OHMS
- AZIMUTH 6 dB BW $\geq 180^\circ$
- ELEVATION 6 dB BW APPROX. 60°
- FRONT TO BACK RATIO OVER 30° ... ≥ 10 dB
- POLARIZATION VERTICAL
- POWER RECEIVE ONLY
- CONNECTOR TNC FEMALE

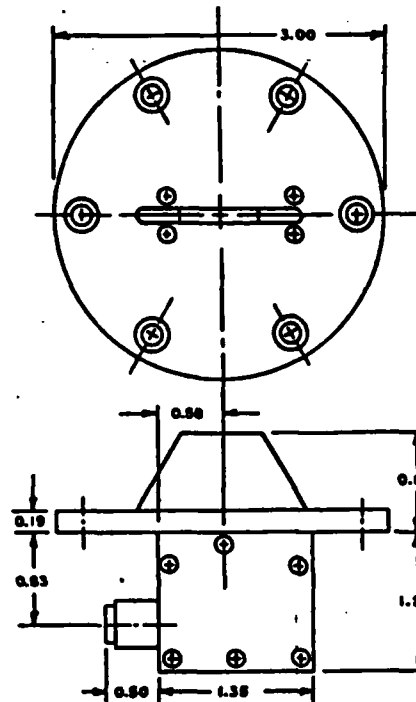


FIGURE 4-21. AVIONICS C-BAND ANTENNA, STUB

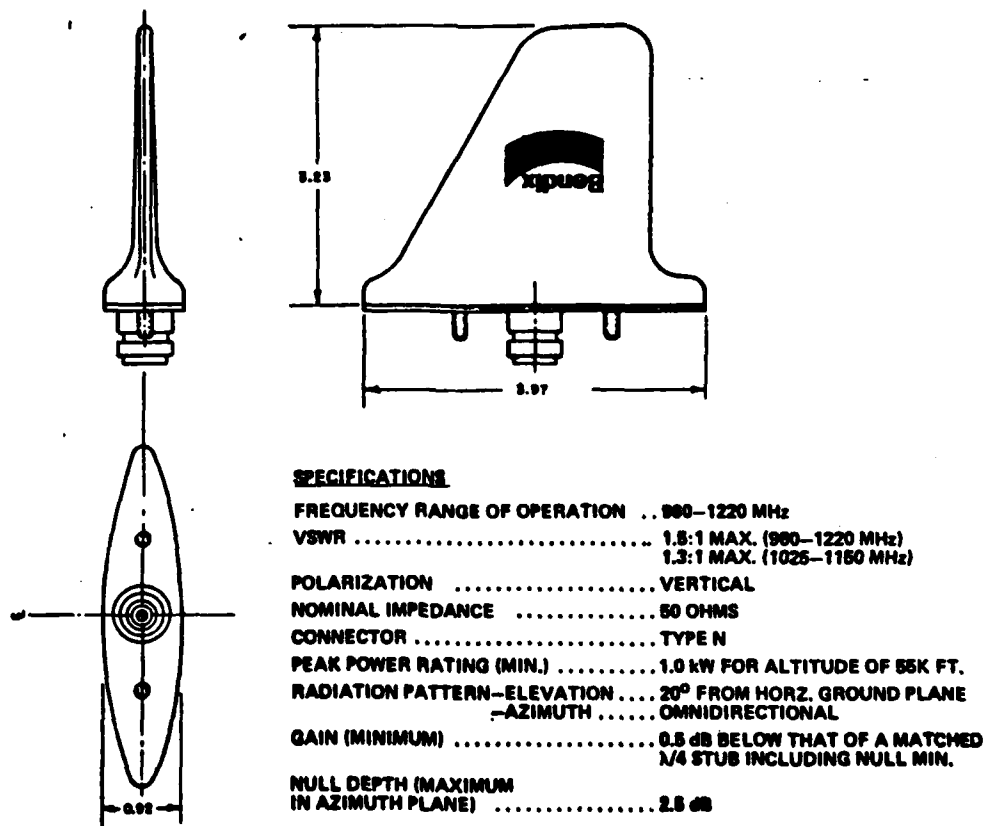


FIGURE 4-22. L-BAND DME ANTENNA

TABLE 4-8. TEST SET SPECIFICATIONS

CHARACTERISTIC	DESCRIPTION
Frequency	C-Band (5031.0 MHz to 5090.7 MHz)
Number of Channels	200
Channel Spacing	300 kHz
Power Requirements	115 Vac 60 Hz
Size	16-3/4" L x 14" W x 6" H
Utility	Bench or Aircraft
RF Output	Attenuator Controlled
Azimuth Coverage	$\pm 40^\circ$
Elevation Coverage	0° to 16°
Beamwidth	1° and 3°
Output Signals	1st and 2nd IF, Final RF for Azimuth, Elevation, Back Azimuth, Back Elevation, Flare, Multipath Beams, Jitter, Side-lobe Suppression, Basic and Small Community Coverage.
Readouts	Gas discharge lamps and thumbwheel switches.

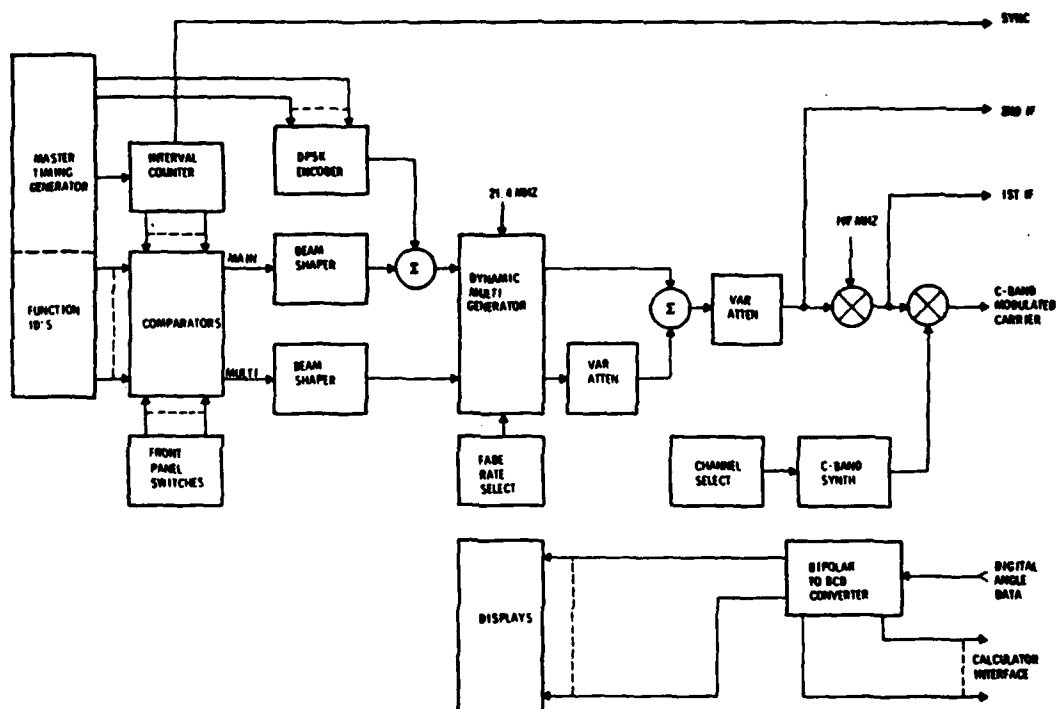


FIGURE 4-23, ANGLE RECEIVER TEST SET BLOCK DIAGRAM

The Angle Receiver Test Set also contains a display section. These displays provide a direct readout of the digital angle data outputs to the angle receiver. By comparing the displayed angle with the angle selected by the test set front panel switches, the proper operation of the angle receiver is easily determined for each particular function. In the event that a function is not properly decoded by the angle receiver, flags are indicated by displaying all dashes for a given function.

Figure 4-24 shows front panel controls. Figure 4-25 shows rear panel controls. The following Table 4-9 describes the function of front panel controls and Table 4-10 describes the function of rear panel controls.

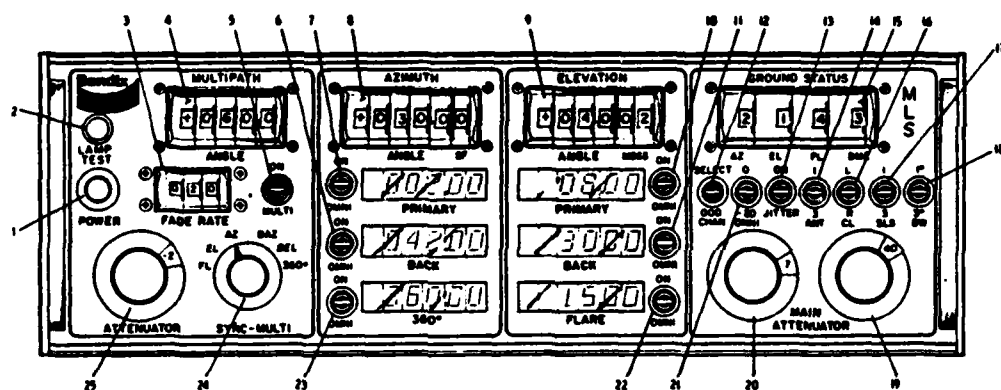


FIGURE 4-24. AIRBORNE TEST SET FRONT PANEL CONTROLS/INDICATORS

TABLE 4-9.. TEST SET FRONT PANEL
CONTROLS/INDICATORS

NO.	FUNCTION
1	Applies 115 Vac, 60 Hz.
2	Push to test for all panel lamps...
3	Selects fade rate in Hz of dynamic multipath.
4	Selects polarity and magnitude of multipath angle signal.
5	ON position generates multipath beam signals. OFF position inhibits multipath.
6	Controls back azimuth (BK AZ) signals. ON position generates beam and omni signals. OMNI position generates omni signal only. Center OFF.
7	Controls primary azimuth angle signal. ON position generates beam and omni signals. OMNI position generates omni signal only. Center OFF.
8	Selects polarity and magnitude of all azimuth functions in increments of a tenth of a degree from +40° to -40°. SF dial selects azimuth deviation scale factor relating to runway length.
9	Selects polarity and magnitude of all elevation functions in increments of a tenth of a degree from +16° to -1.0°. MSGs indicates minimum selectable glide slope.
10	Controls primary elevation angle signals. ON position generates beam and omni signals. OMNI position generates omni signal only. Center OFF.
11	Controls back elevation angle signal. ON position generates beam and omni signals. OMNI position generates omni signal only. Center OFF.
12	In the SELECT position, rear panel channel selector switch active. In the 000 position overrides rear panel channel switch and establishes operation in channel 000.
13	ON position simulates ground station jitter to reduce prop modulation.
14	Selects antenna 1, 2, or 3.
15	Selects azimuth, elevation, flare or DME ground status.

TABLE 4-9. .TEST SET FRONT PANEL
CONTROLS/INDICATORS (CONTINUED)

NO.	FUNCTION
16	Selects either left or right clearance. Center position inhibits all clearance pulses.
17	SLS pulse off in center position. Both SLS pulses 2 dB below main beam. Position 1, right SLS pulse 2 dB greater than main beam. Position 3, left SLS pulse 2 dB less than main beam.
18	Selects either 1 or 3 degree beamwidth as measured at the 3 dB points.
19	Controls amplitude of test set RF output level from 0 dBm to -60 dBm. (See number 20.)
20	Selected value adds to value set by 19 above.
21	Selects magnitude of omni as measured in dB down from the peak magnitude of the main beam.
22	Controls flare function. ON position generates beam and omni signals. OMNI position generates omni only. Center OFF.
23	Controls 360° azimuth. ON generates beam and omni. OMNI position generates omni only. Center OFF.
24	Selects function to include multipath and syncs that function with rear panel output jack for scope use.
25	Sets amplitude of multipath beam measured in dB from amplitude of main beam.

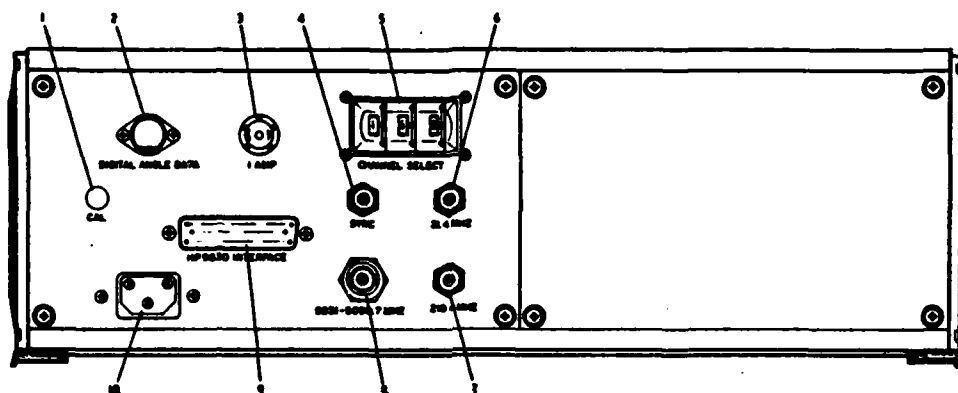


FIGURE 4-25. AIRBORNE TEST SET, REAR PANEL
CONTROLS/CONNECTORS

TABLE 4-10. REAR PANEL TEST SET
CONTROLS/CONNECTORS

NO.	FUNCTION
1	CAL - This is a momentary switch that allows the user to measure the power output of the test set. When pushed, it injects a dc level equal to the peak amplitude of the bi-polar DPSK modulation signal. This produces a CW signal at each of the 21.4, 219.4 and 5031-5090.7 MHz outputs which, when measured on a spectrum analyzer, will give the equivalent power content of the DPSK message.
2	DIGITAL ANGLE DATA - This connector accepts a cable from the test rack which carries a signal from the angle receiver. This signal drives the display section of the test set to provide the angle readouts.
3	1 AMP - 1 amp slo-blow fuse.
4	SYNC - Provides a signal suitable for use as an oscilloscope trigger to view the log video output of the angle receiver.
5	CHANNEL SELECT - With front panel switch 12 set to the "SELECT" position, this switch allows selection of the C-band synthesizer channels from 000 to 199.
6	21.4 MHz - Provides a properly modulated test signal at 21.4 MHz.
7	219.4 MHz - Provides a properly modulated test signal at 219.4 MHz.
8	5031-5090.7 MHz - Provides a properly modulated test signal in the range of 5031-5090.7 MHz, depending on the channel selected by switch 5.
9	HP 9830 - Provides interface between the test set and the HP 9830 calculator for statistical error analysis of the angle receiver.
10	115 VOLTS 60 Hz AC - Input power.

4.10 APPLICABLE DOCUMENTS

Technical manuals that contain additional and more detailed information on the MLS airborne equipment are listed below.

<u>TITLE</u>	<u>PUBLICATION NO.</u>
Microwave Landing System, Airborne Subsystem, Small Community Configuration, Instruction Manual	TI-6850.25 IB1157-1
Microwave Landing System, Airborne Subsystem, Small Community Configuration, Maintenance Manual	Not Assigned IB1157
Microwave Landing System, Airborne Subsystem, Basic Narrow Configuration, Instrucation Manual	Not Assigned IB1157
Microwave Landing System, Airborne Subsystem, Basic Narrow Configuration, Maintenance Manual	Not Assigned IB1157C
Microwave Landing System, Airborne Test Set, Maintenance Manual	TI-6850.27 IB1157A
Microwave Landing System, Airborne Test Set, Instruction Manual	Not Assigned IB1157A
Microwave Landing System, DME Precision Interrogator System, Maintenanct Manual	Not Assigned 1B1157B
Microwave Landing System, DME Precision Interrogator System, Instruction Manual	Not Assigned

SECTION 5.

TEST PROGRAM AND RESULTS

5.1 INTRODUCTION

This section contains a descriptive review of all testing performed during the Phase III development effort. This includes incoming inspection of components, subassembly tests, drawer level tests, and antenna assembly tests performed at Bendix Communications Division. Paragraph 5.3 contains sample results of system flight tests performed at NAFEC.

Due to the voluminous nature of the complete test program results, it is not practical to include all test data. When the tests are discussed, the availability of the test data is described. The following paragraph describes the tests performed at the Bendix Communications Division.

5.2 FACTORY TESTS AT BENDIX

The primary objectives of the factory tests performed by Bendix during the Phase III prototype implementation of the ground equipment subsystems were to ensure system reliability and performance. There were four levels of tests performed during the Phase III prototype implementation. These were:

- (a) Incoming Inspection
- (b) Component Tests
- (c) Subassembly Tests
- (d) Subsystem Tests

The following paragraphs discuss the methods of testing implemented during the Phase III development effort. No test data is included as part of this section, except for antenna range accuracy tests. All pertinent test data on the Phase III development program is available at the Bendix Communications Division MLS Program Office.

5.2.1 Incoming Inspection

Incoming inspection was invoked on only selected items as deemed necessary by the Bendix Engineering Department. Incoming inspection concentrated on blank printed circuit cards and lens cables. All integrated circuits were purchased to MIL specifications and were not subjected to incoming inspection. All other major components or materials, such as RF switches, exciter units, transmitter modules, radomes, power supplies, etc., were procured or subcontracted against detailed specifications and test requirements. In these cases, source inspection and test data were required.

5.2.2 Component Tests

There were tests made on completed PC cards, minor sub-assemblies and items purchased against catalog specifications. As deemed necessary by Bendix Engineering, these components were tested both at room ambient temperatures and at the low and high temperature limits of -10 degrees C and +50 degrees C.

There were approximately 60 test specifications and tests performed on components. These specifications and data sheets are on file in the MLS Program Office.

5.2.3 Subassembly Tests

5.2.3.1 Electronic Unit Tests - Subassembly testing was performed on each completed equipment drawer and other major sub-assemblies such as antennas. The drawer level tests checked out the functional operation of each drawer. At this time, preliminary adjustments were made to timing, thresholds, power levels, etc.

For reference purposes, the subassemblies are listed in Table 5-1 by name and subassembly part number. Copies of the test data sheets are filed in the MLS Program Office.

5.2.3.2 Antenna Assembly Range Tests - Each antenna for both the Basic Narrow and Small Community systems was thoroughly tested on an outdoor test range for static patterns and dynamic pointing errors. Figure 5-1 is a block diagram of the test range system.

5.2.3.2.1 Static Pattern Tests - Static patterns were obtained by addressing the beam steering electronics via an HP 9830 calculator keyboard.

Figures 5-2a through 5-2e are typical static patterns for the Basic Narrow AZ antenna at the angles indicated on each figure.

Figures 5-3a through 5-3d are static patterns for Basic Narrow EL; Figures 5-4a through 5-4d are static patterns for Small Community AZ; and Figures 5-5a through 5-5d are for Small Community EL.

5.2.3.2.2 Gain Tests - Gain tests were made by the substitution method using a standard gain horn. Tables 5-2 through 5-5 summarize the gains of each antenna assembly. Gain measurements were made at the input to the fine scan modulator.

5.2.3.2.3 Beamwidth Tests - Beamwidths were obtained by mechanically rotating the beam past the receiving horn and recording the received amplitudes. Beamwidths were then computed on the HP 9830 by curve fitting to the data, then finding the width between 3 dB points. Tables 5-6 through 5-9 give the beamwidths for each antenna.

TABLE 5-1. SUBASSEMBLY TEST SPECIFICATION NUMBERS

SUBASSEMBLY	SPECIFICATION NO.
<u>BASIC NARROW AZIMUTH</u>	
TWT Amplifier	4042589-0701
RF Unit	4041054-0501
Local Control/Status	4041958-0501
Maintenance Monitor	4041954-0501
Monitor Power Supply	4043321-0501
Electronics Power Supply	4043312-0501
Cooling Fan	4042003-0501
Remote Control/Status	4041953-0501
AC Control Panel	4041265-0501
<u>BASIC NARROW ELEVATION</u>	
TWT Amplifier	4041225-0701
RF Unit	4041054-0501
Local Control/Status	4043154-0501
Maintenance Monitor	4041952-0501
Monitor Power Supply	4043321-0502
Electronics Power Supply	4043360-0501
Cooling Fan	4042003-0501
AC Control Panel	4041265
<u>SMALL COMMUNITY AZIMUTH</u>	
TWT Amplifier	4042612-0701
RF Unit	4041056-0501
Local Control/Status	4043155-0501
Maintenance Monitor	4041951-0501
Monitor Power Supply	4043350-0501
Remote/Status	4043138-0501
<u>SMALL COMMUNITY ELEVATION</u>	
TWT Amplifier	4042612-0701
RF Unit	4041056-0501
Local Control/Status	4043156-0501
Maintenance Monitor	4043147-0501
Monitor Power Supply	4043350-0501

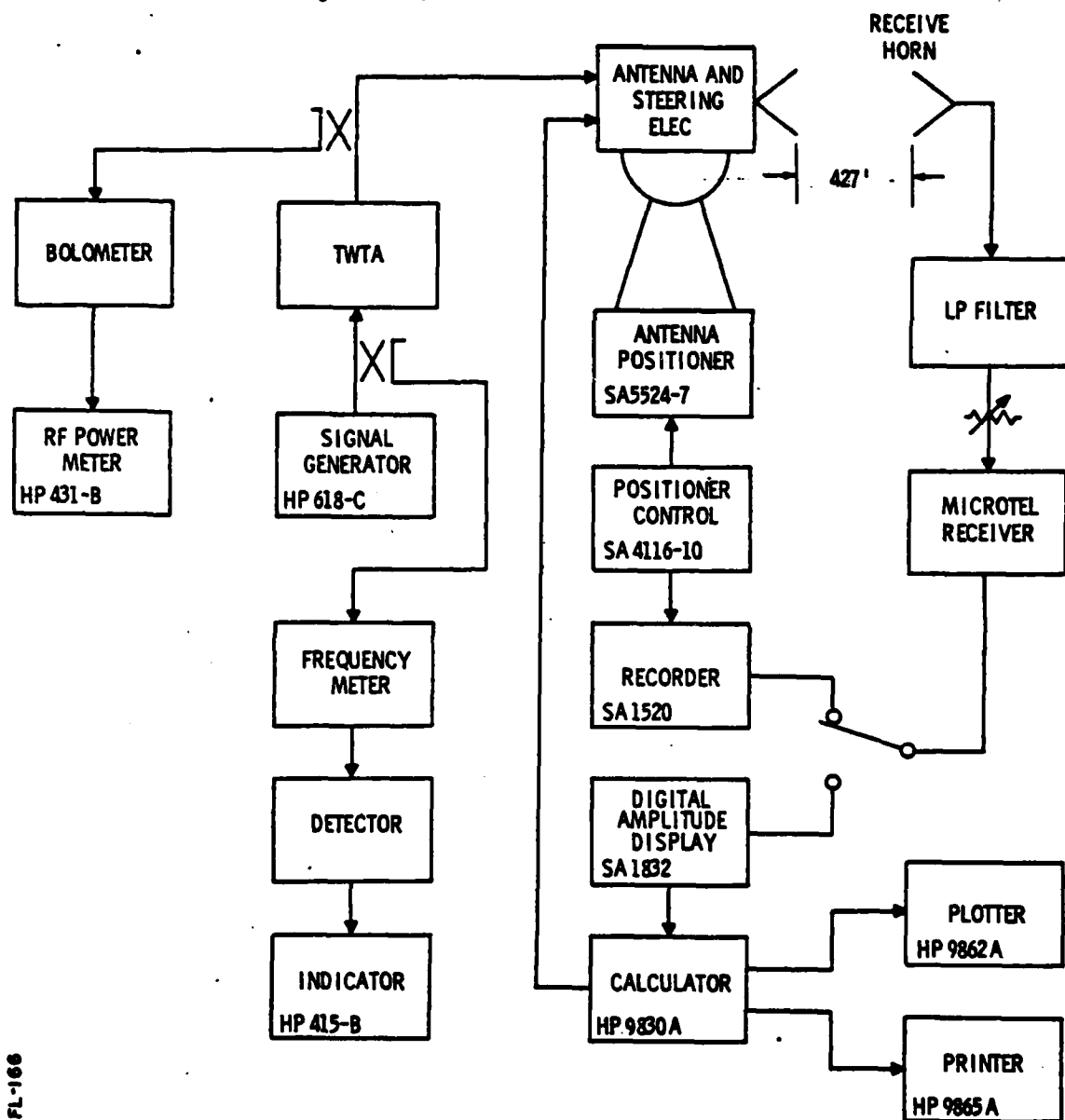


FIGURE 5-1. TEST RANGE SYSTEM, BLOCK DIAGRAM

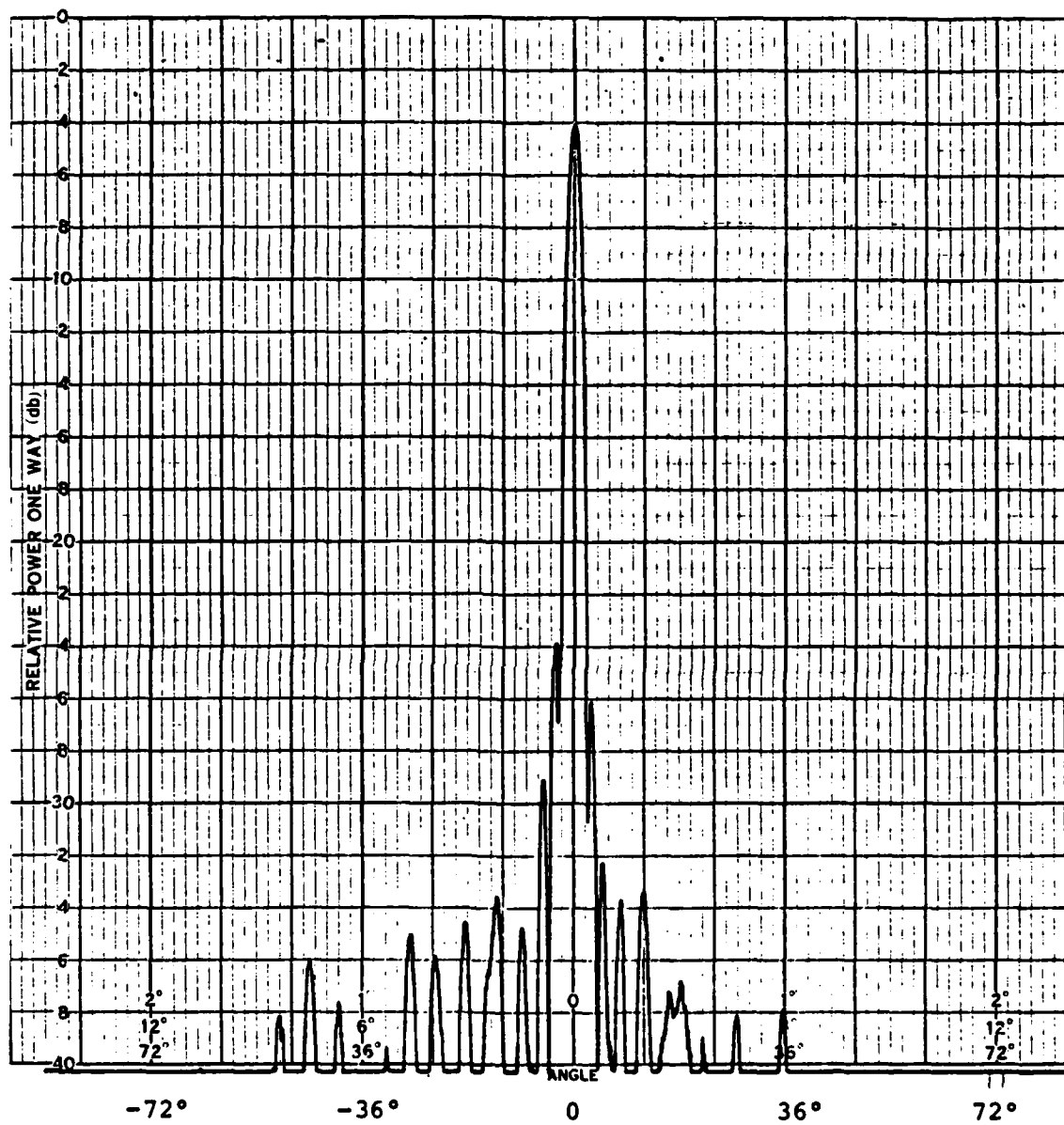


FIGURE 5-2a. STATIC AZIMUTH PATTERN, BN AZ,
0 DEGREE

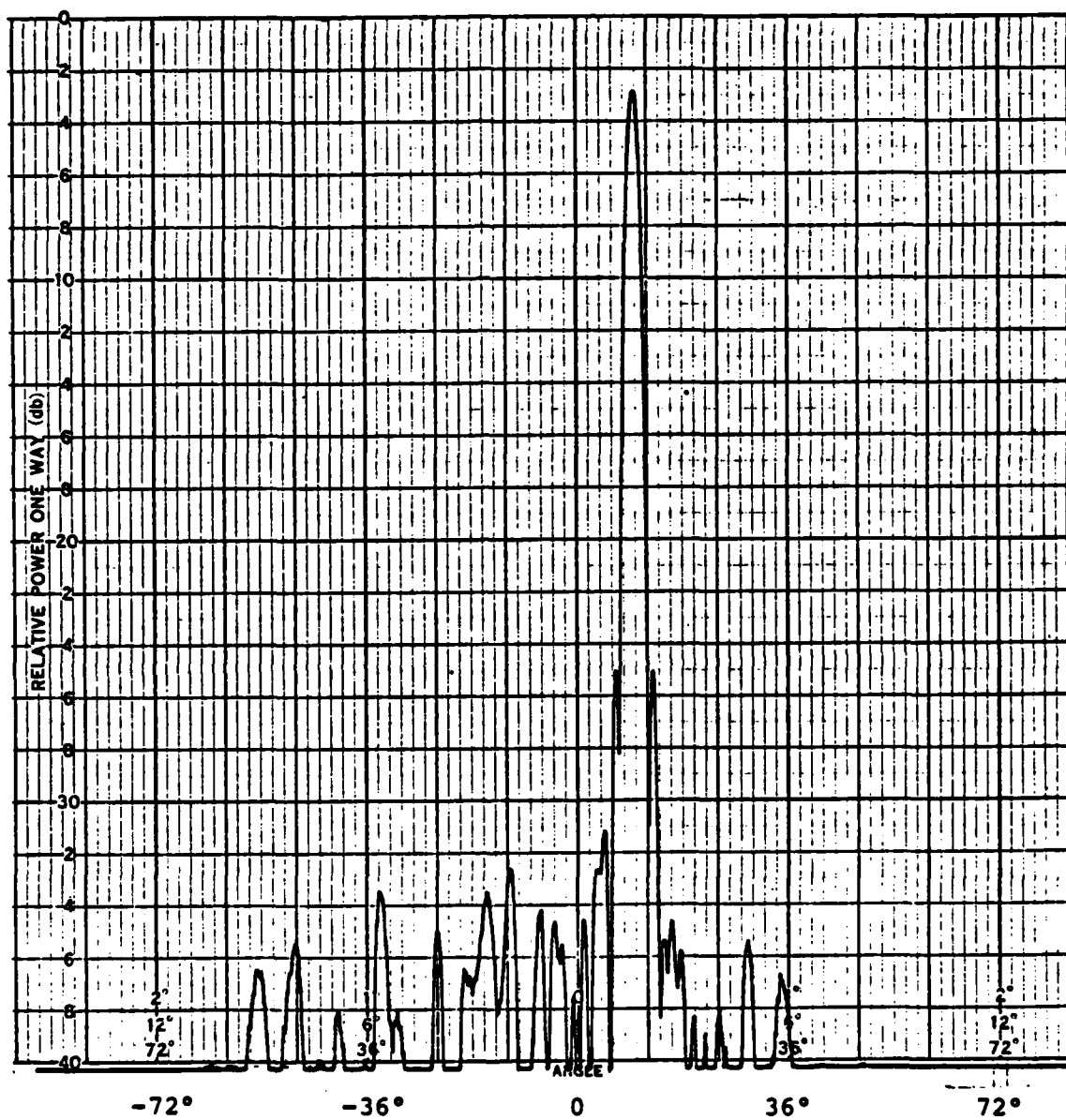


FIGURE 5-2b. . STATIC AZIMUTH PATTERN, BN AZ,
10.09 DEGREES

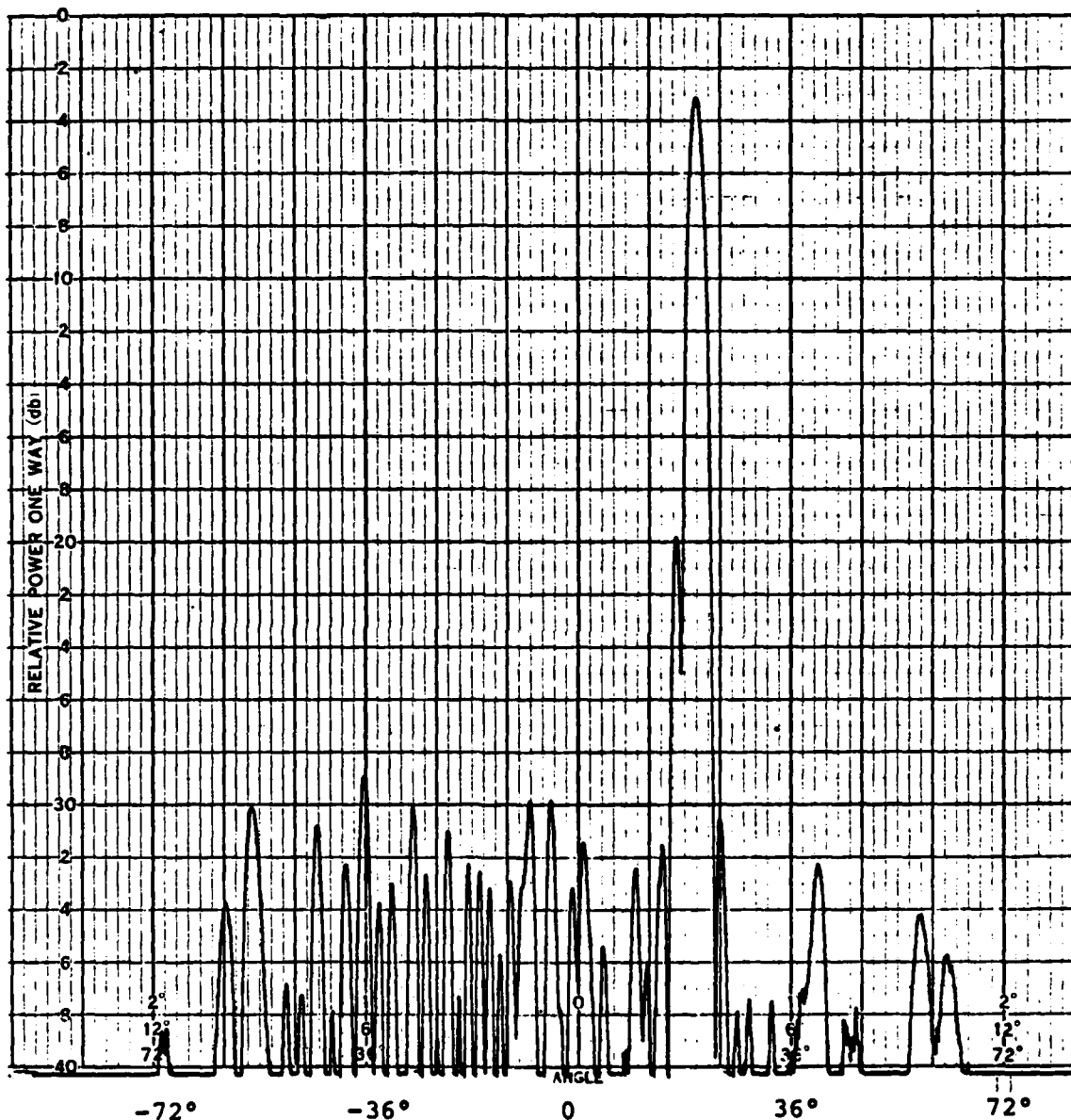


FIGURE 5-2c. STATIC AZIMUTH PATTERN, BN AZ,
20.18 DEGREES

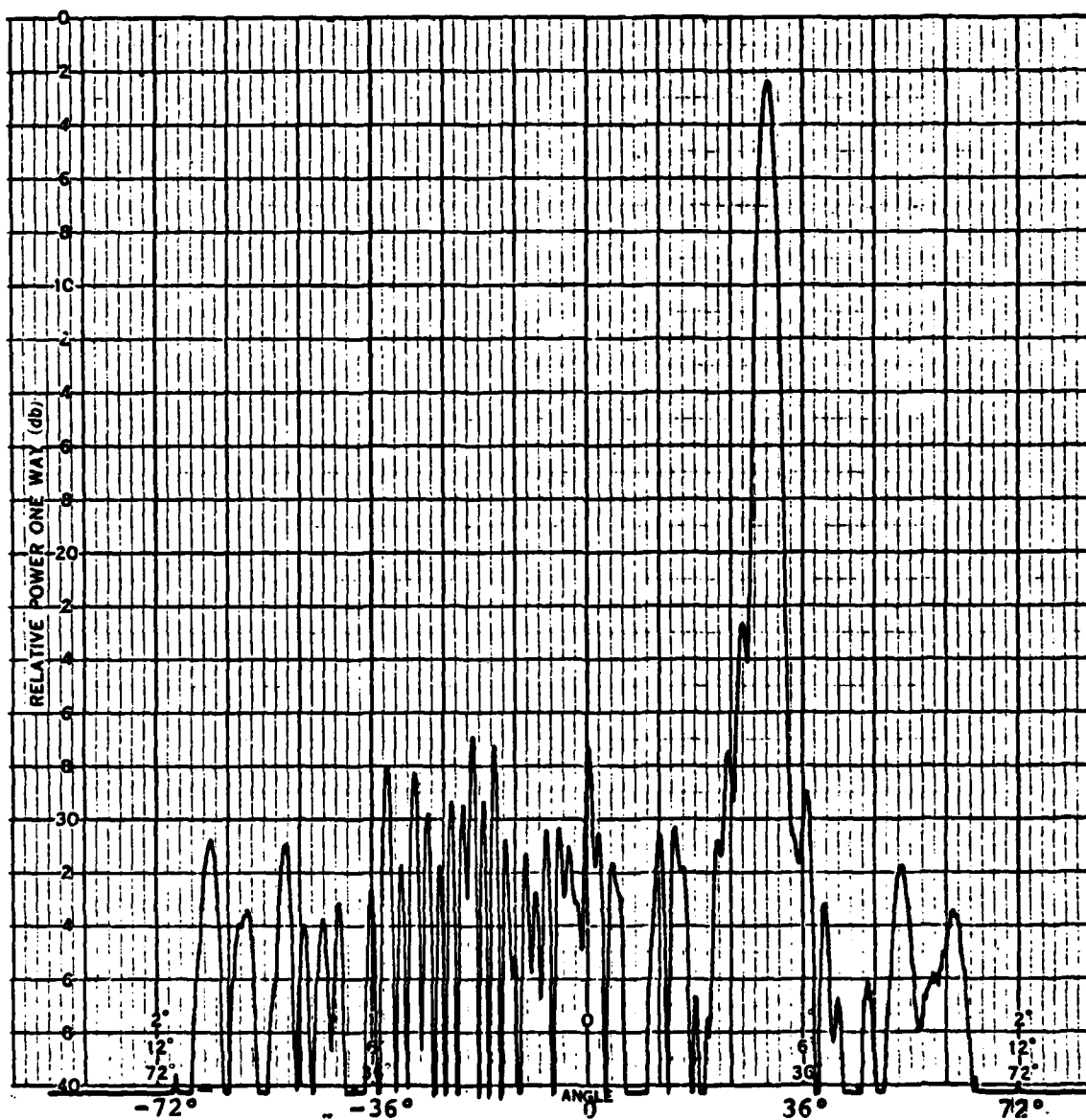


FIGURE 5-2d. STATIC AZIMUTH PATTERN, BN AZ,
30.50 DEGREES

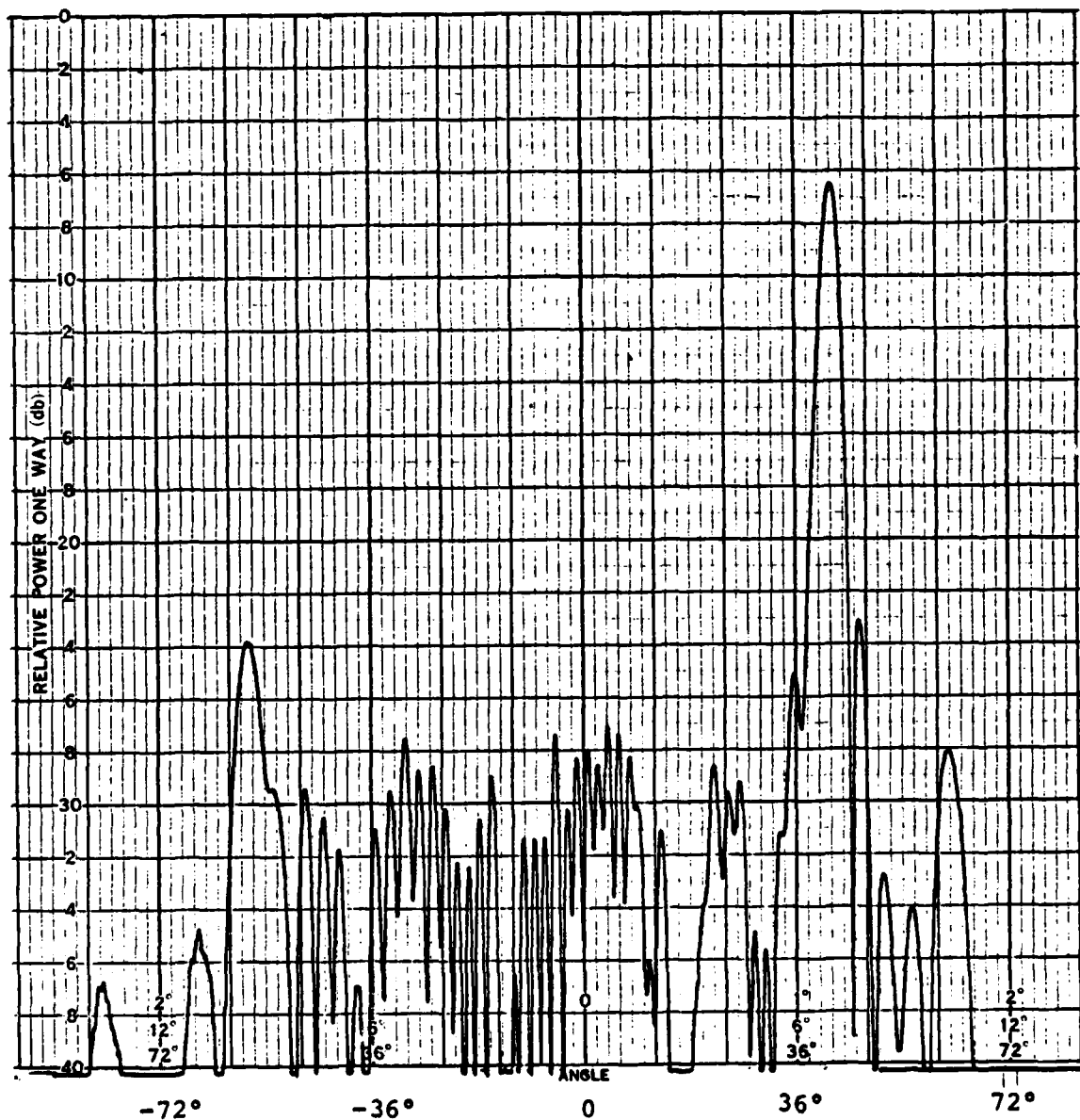


FIGURE 5-2e. STATIC AZIMUTH PATTERN, BN AZ,
41.78 DEGREES

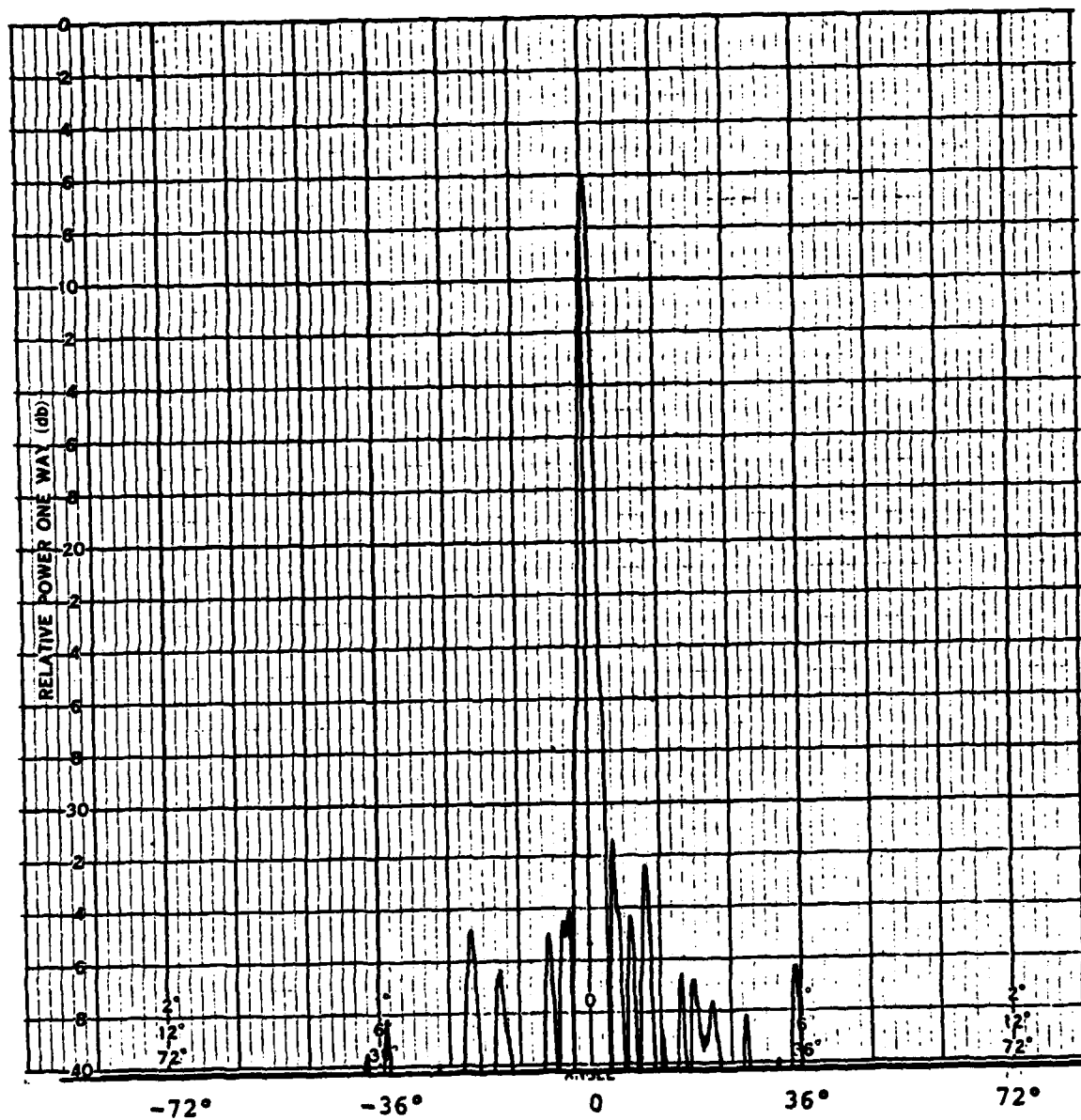


FIGURE 5-3a. STATIC ELEVATION PATTERN, BN EL,
0 DEGREE

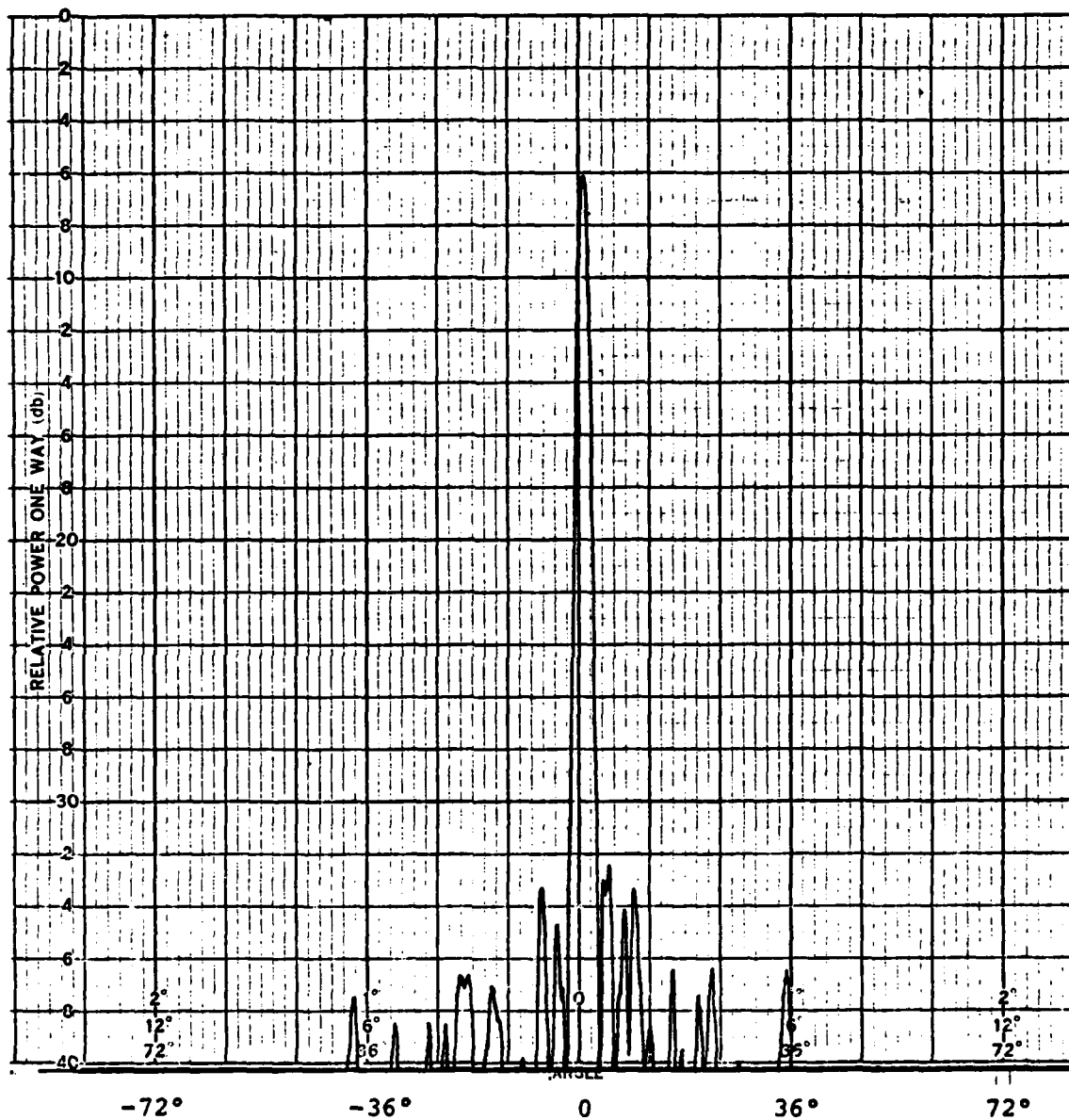


FIGURE 5-3b. STATIC ELEVATION PATTERN, BN EL,
0.495 DEGREE

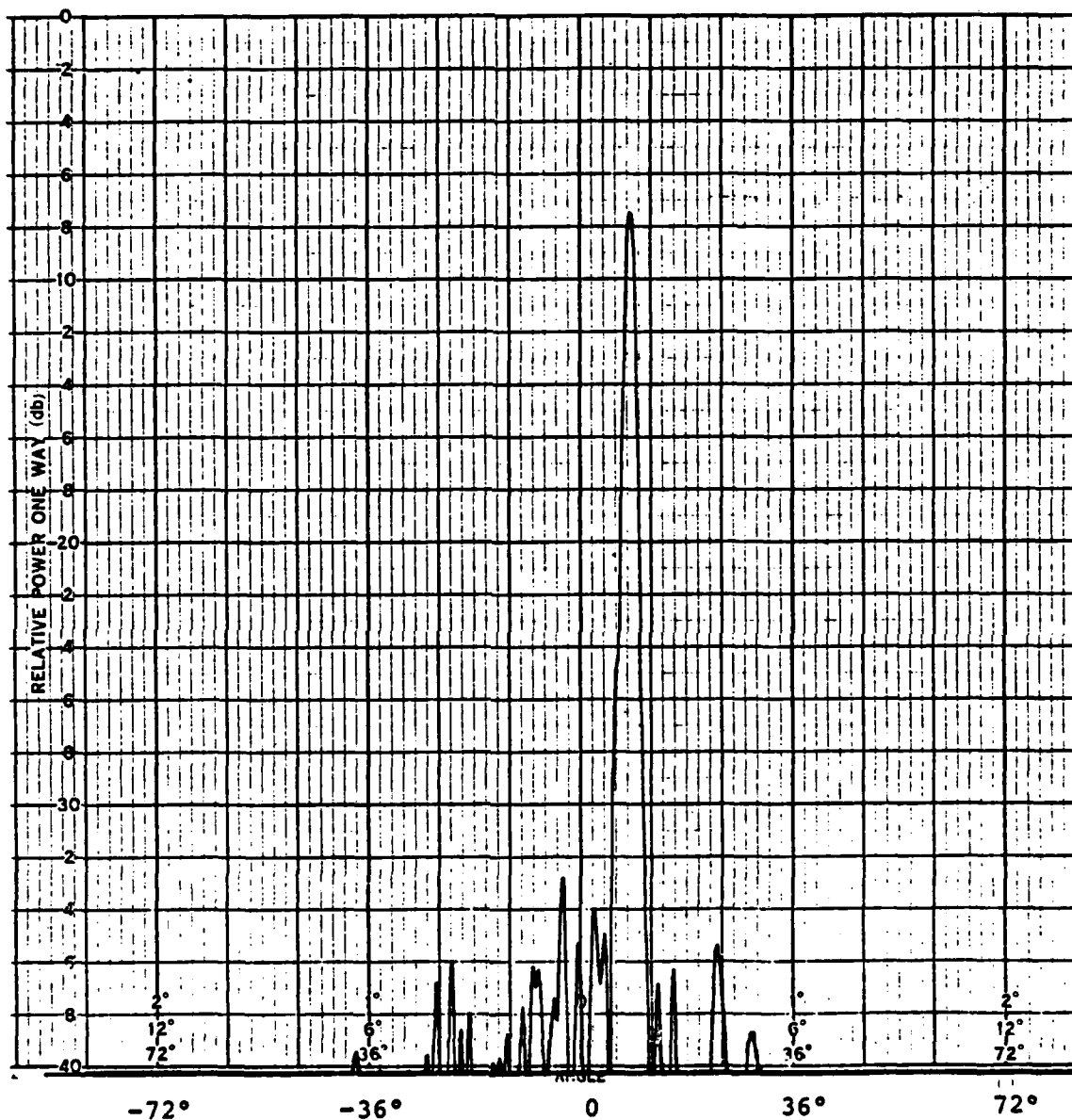


FIGURE 5-3c. STATIC ELEVATION PATTERN, BN EL,
8.797 DEGREES

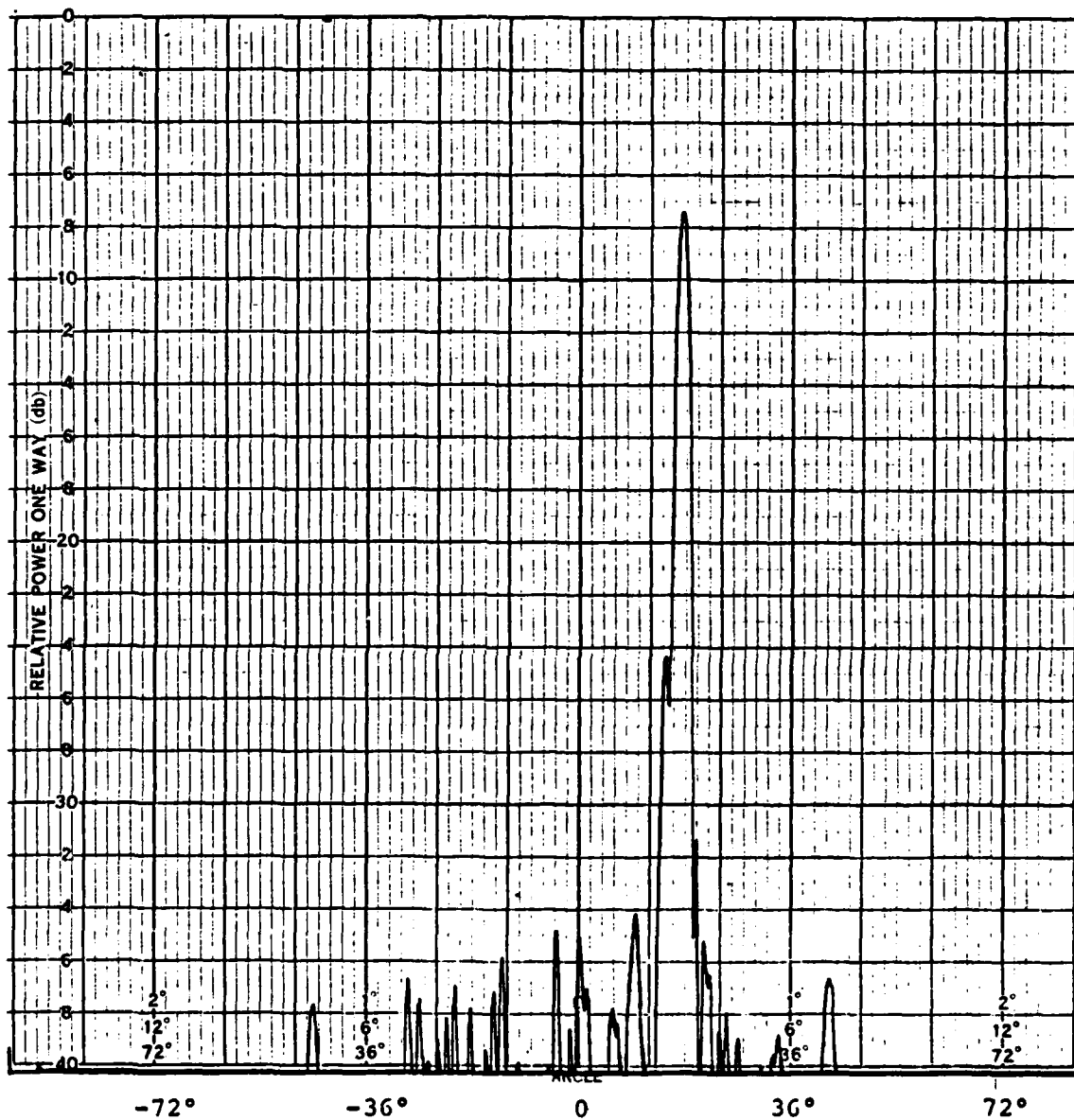


FIGURE 5-3d. STATIC ELEVATION PATTERN, BN EL,
17.587 DEGREES

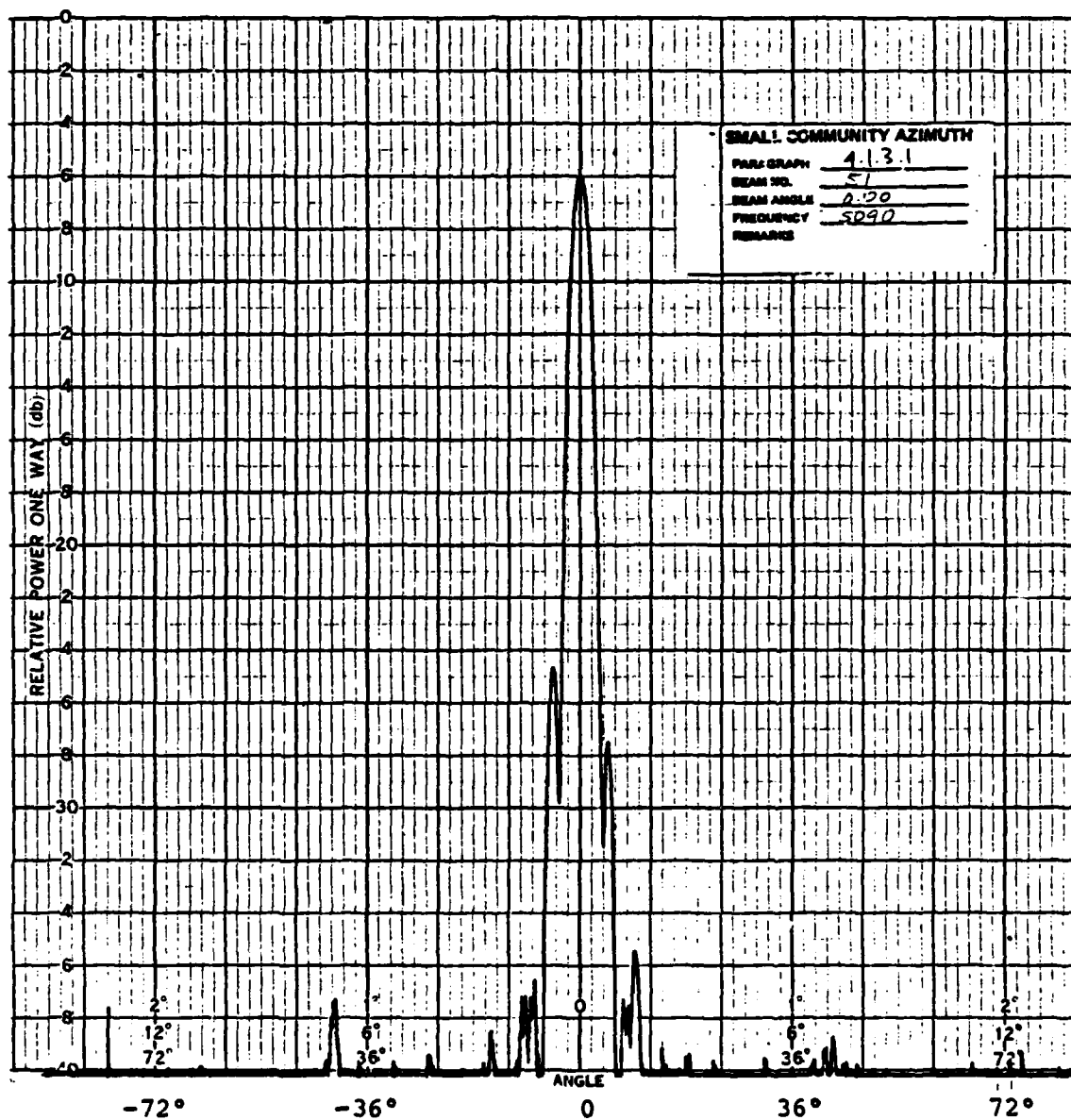


FIGURE 5-4a. STATIC AZIMUTH PATTERN, SC AZ,
0 DEGREE

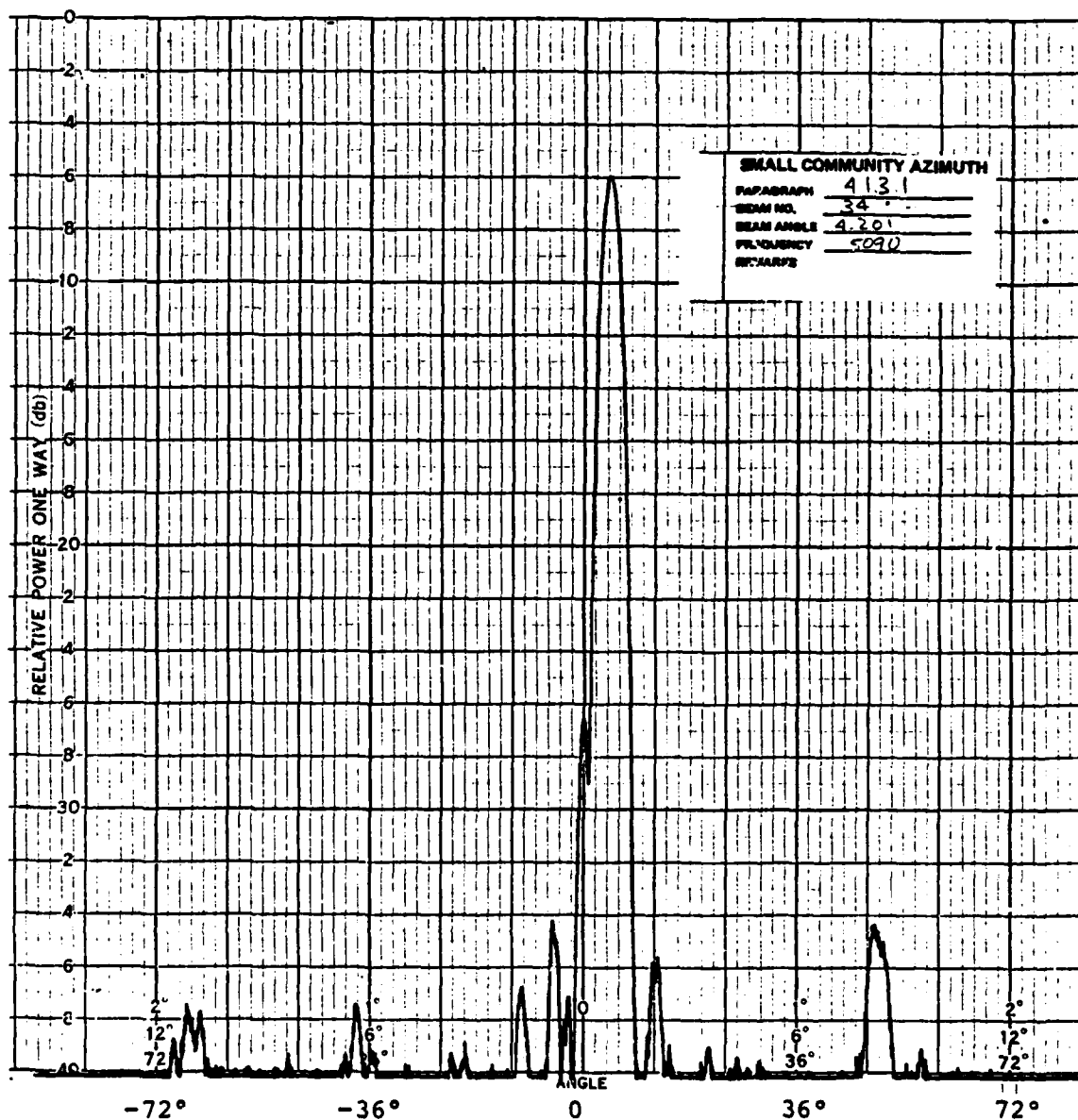


FIGURE 5-4b. STATIC AZIMUTH PATTERN, SC AZ,
4.201 DEGREES

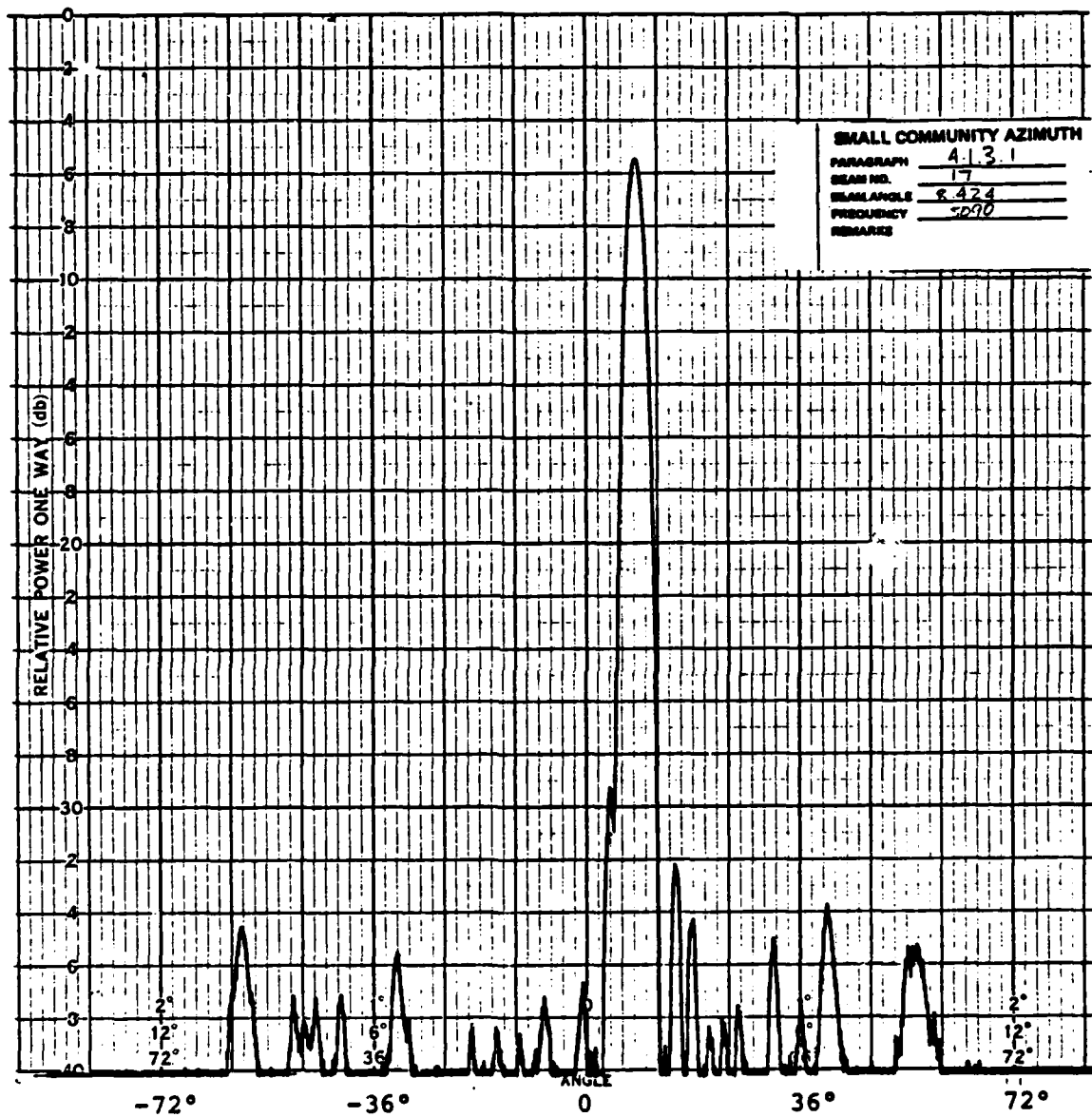


FIGURE 5-4c. STATIC AZIMUTH PATTERN, SC AZ,
8.424 DEGREES

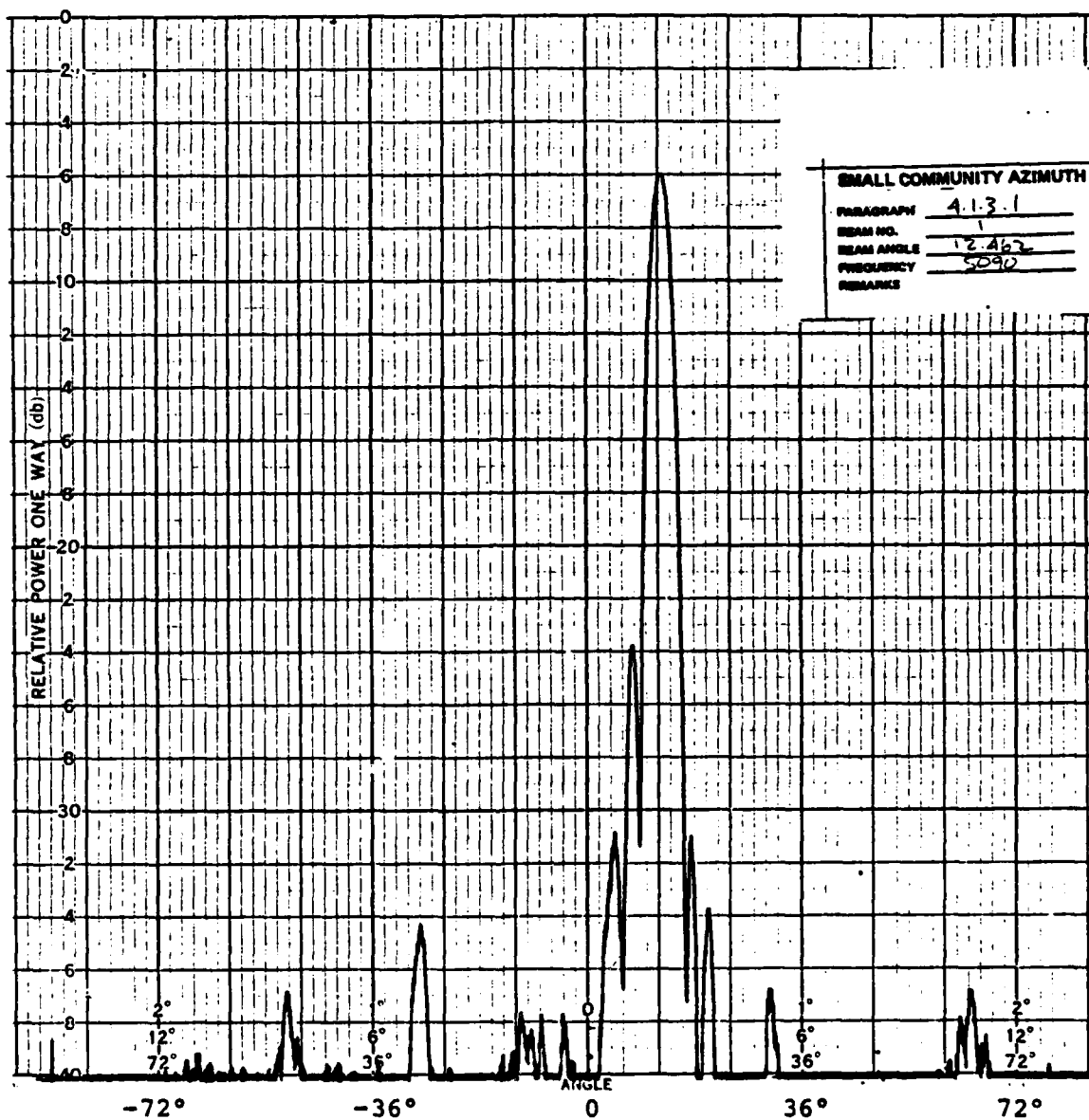


FIGURE 5-4d. STATIC AZIMUTH PATTERN, SC AZ,
12.462 DEGREES

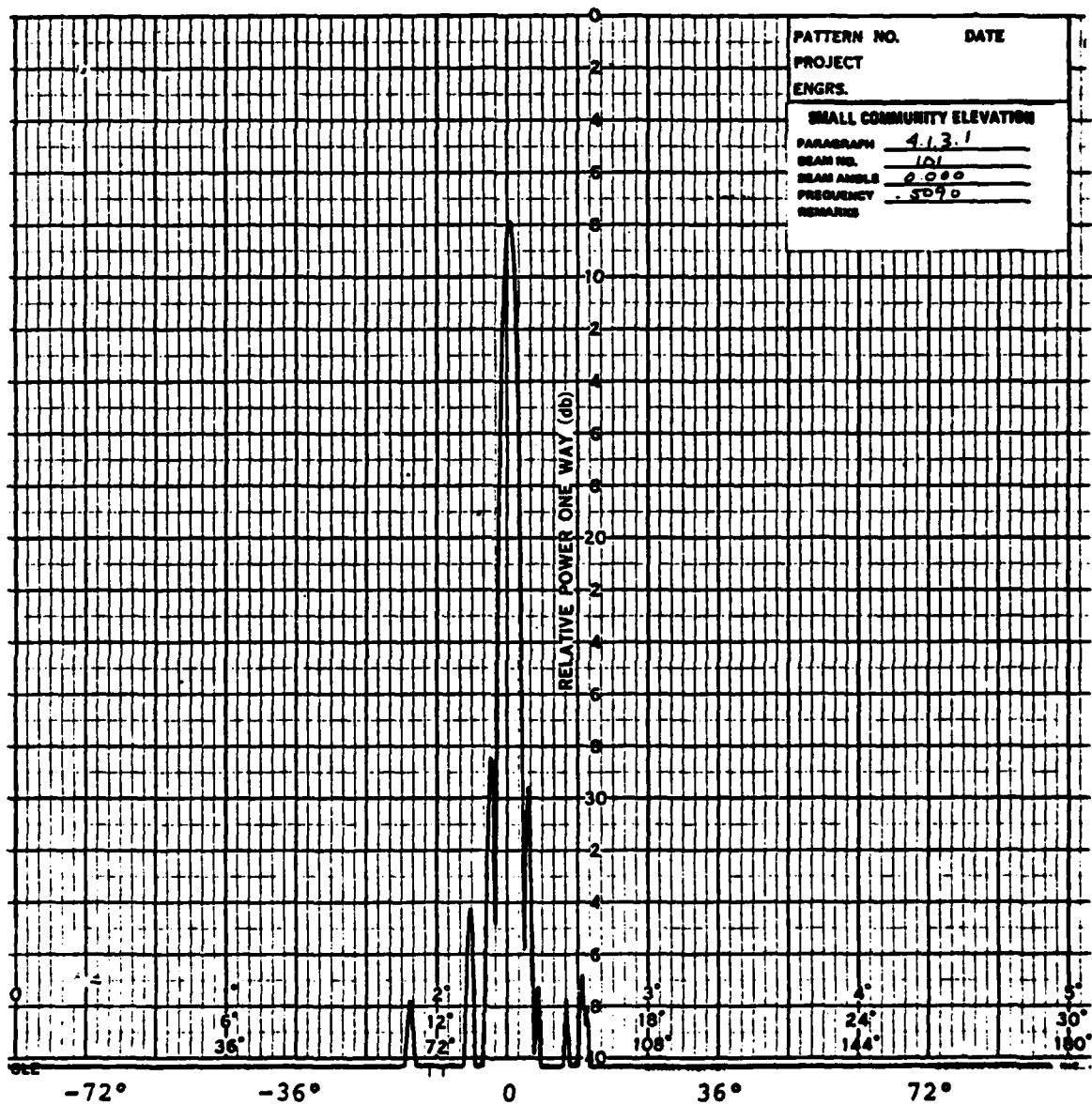


FIGURE 5-5a. STATIC ELEVATION PATTERN, SC EL,
0 DEGREE

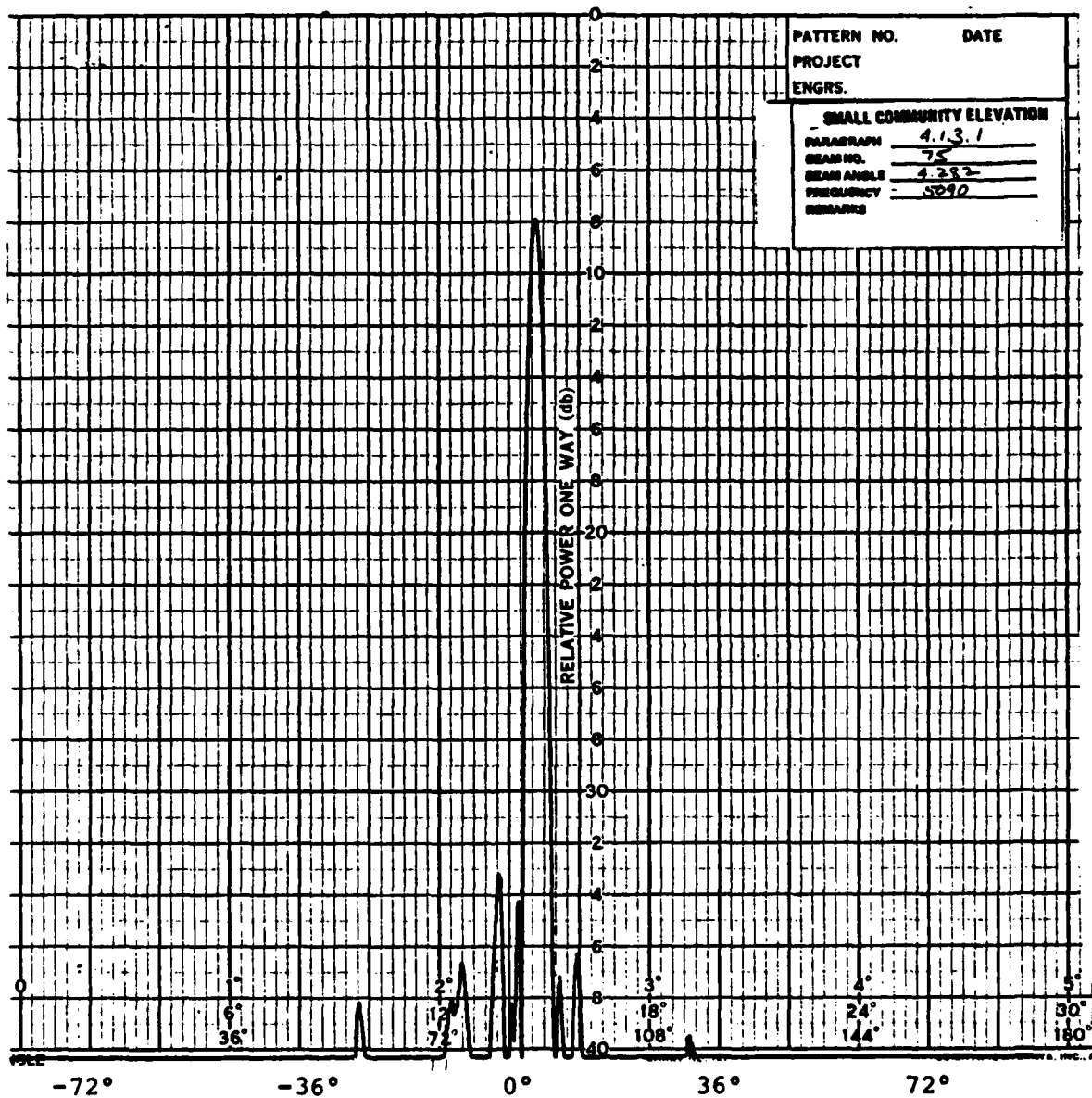


FIGURE 5-5b. STATIC ELEVATION PATTERN, SC EL,
4.282 DEGREES

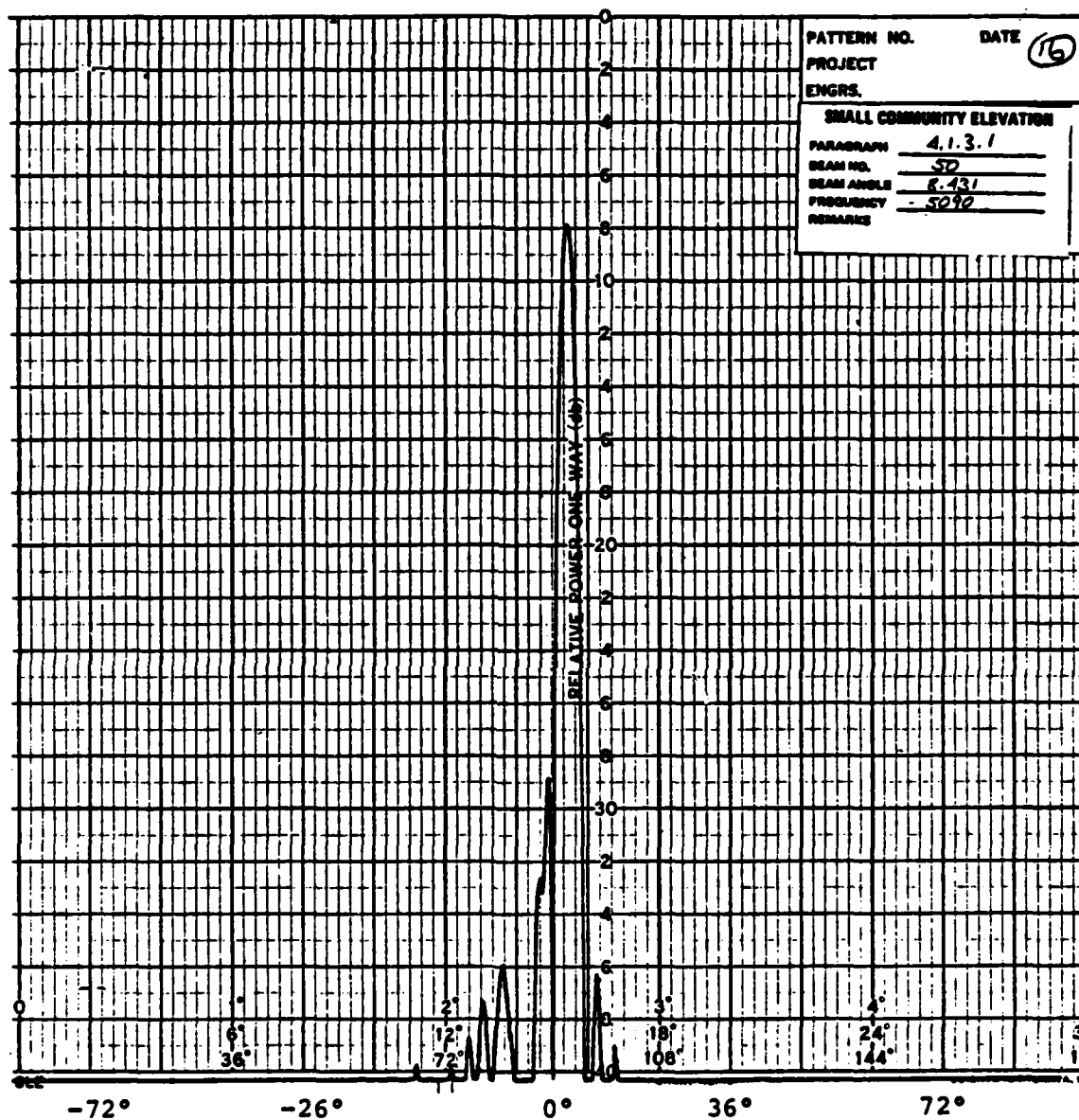


FIGURE 5-5c. STATIC ELEVATION PATTERN, SC EL,
8.431 DEGREES

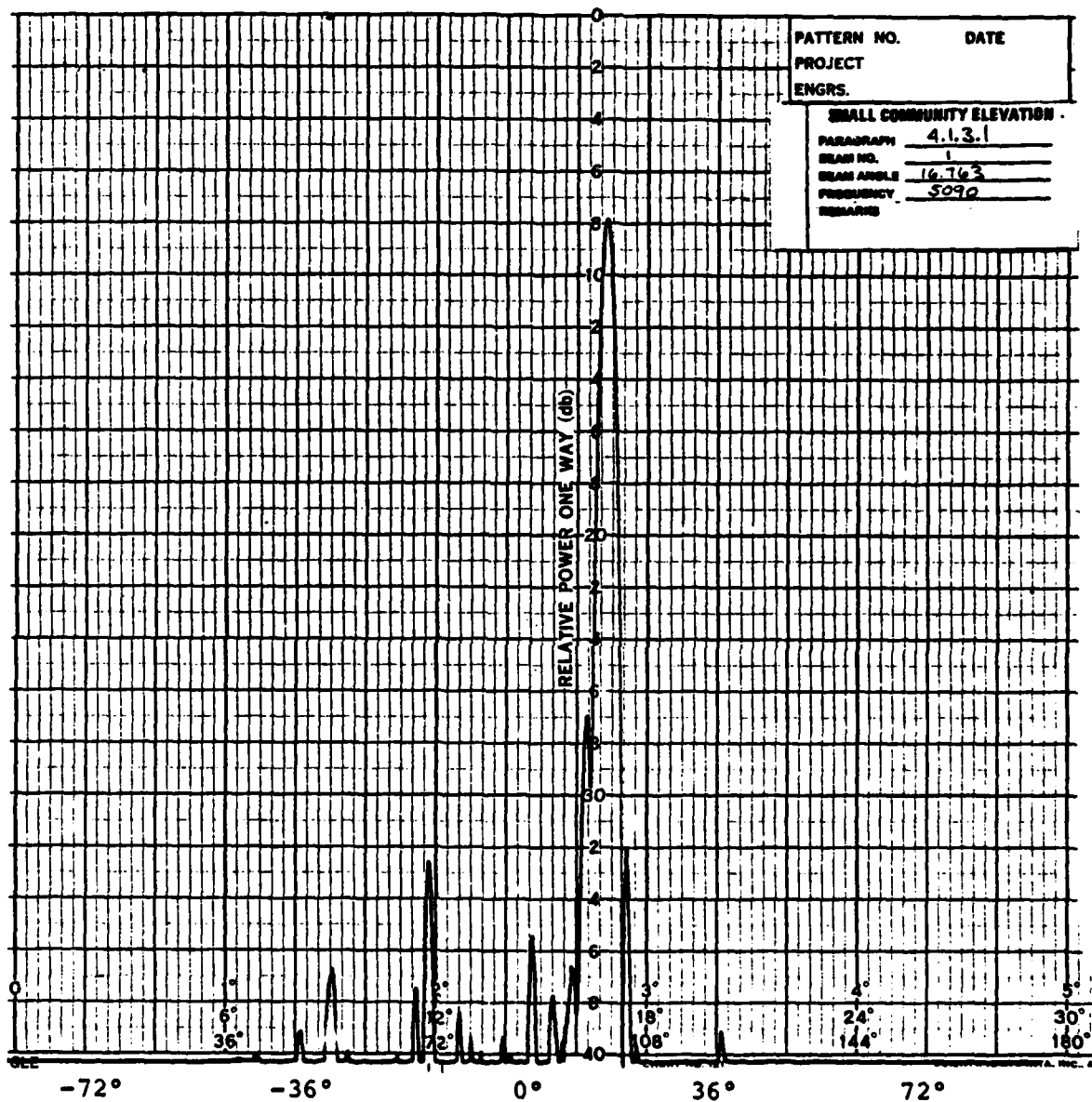


FIGURE 5-5d. STATIC ELEVATION PATTERN, SC EL,
16.763 DEGREES

TABLE 5-2. BASIC NARROW AZIMUTH GAIN

BEAM STEP NO.	BEAM ANGLE (Degrees)	GAIN (dBi) 5030 MHz.	GAIN (dBi) 5060 MHz	GAIN (dBi) 5090 MHz
1	41.718	22.8	22.8	22.8
112	20.010	24.5	24.2	24.1
231	0.000	24.8	24.3	24.3
350	-20.010	25.2	24.8	24.8
461	-41.718	22.6	22.8	23.3
IDENTIFICATION ANTENNA		14.6	14.8	13.8

TABLE 5-3. BASIC NARROW ELEVATION GAIN

BEAM STEP NO.	BEAM ANGLE (Degrees)	GAIN (dBi) 5030 MHz	GAIN (dBi) 5060 MHz	GAIN (dBi) 5090 MHz
1	17.587	20.4	20.6	21.4
69	8.922	21.1	20.8	20.4
141	0.000	21.3	21.1	20.4
IDENTIFICATION ANTENNA		15.2	14.2	14.4
UPPER SLS ANTENNA		8.8	8.6	9.1

TABLE 5-4. SMALL COMMUNITY AZIMUTH ANTENNA GAIN

BEAM STEP NO.	BEAM ANGLE (Degrees)	GAIN (dBi) 5030 MHz	GAIN (dBi) 5060 MHz	GAIN (dBi) 5090 MHz
1	+12.462	23.6	23.5	23.3
51	0.000	24.4	24.0	24.0
101	-12.462	23.8	23.8	23.8
IDENTIFICATION ANTENNA		14.6	14.8	13.8
FLY RIGHT BEAM		18.8	18.3	17.8
FLY LEFT BEAM		18.5	17.8	17.3

TABLE 5-5. SMALL COMMUNITY ELEVATION ANTENNA GAIN

BEAM STEP NO.	BEAM ANGLE (Degrees)	GAIN (dBi) 5030 MHz	GAIN (dBi) 5060 MHz	GAIN (dBi) 5090 MHz
1	16.763	20.76	20.3	20.64
51	8.264	21.16	20.6	20.84
101	0.000	21.36	20.6	20.74
IDENTIFICATION ANTENNA		14.7	14.9	14.7
UPPER SLS ANTENNA		8.16	8.4	8.14

TABLE 5-6. BASIC NARROW AZIMUTH BEAMWIDTHS

BEAM STEP NO.	BEAM ANGLE (Degrees)	BEAMWIDTH (Degrees) 5030 MHz	BEAMWIDTH (Degrees) 5060 MHz	BEAMWIDTH (Degrees) 5090 MHz
1	41.718	2.96	2.9	2.88
55	30.503	*	2.52	*
111	20.187	*	2.22	*
170	10.090	*	2.02	*
200	5.107	2.00	1.97	2.06
231	0.000	1.99	2.01	1.98
250	-3.128	2.01	2.02	1.99
309	-12.947	*	2.06	*
367	-23.035	*	2.32	*
420	-33.059	*	2.68	*
461	-41.718	3.05	2.90	2.9
* Not Measured				

TABLE 5-7. BASIC NARROW ELEVATION ANTENNA BEAMWIDTHS

BEAM STEP NO.	BEAM ANGLE (Degrees)	BEAMWIDTH (Degrees) 5030 MHz	BEAMWIDTH (Degrees) 5060 MHz	BEAMWIDTH (Degrees) 5090 MHz
1	17.587	1.64	1.69	1.64
18	15.385	1.61	1.62	1.62
35	13.209	1.55	1.54	1.56
52	11.055	1.60	1.59	1.58
69	8.922	1.59	1.61	1.63
86	6.804	1.58	1.57	1.55
103	4.692	1.53	1.51	1.53
120	2.591	1.53	1.52	1.51
137	0.495	1.55	1.49	1.50
141	0.000	1.54	1.50	1.50

TABLE 5-8. SMALL COMMUNITY AZIMUTH ANTENNA BEAMWIDTHS

BEAM STEP NO.	BEAM ANGLE (Degrees)	BEAMWIDTH (Degrees) 5030 MHz	BEAMWIDTH (Degrees) 5060 MHz	BEAMWIDTH (Degrees) 5090 MHz
1	12.462	3.12	3.08	3.07
17	8.424	2.92	2.95	2.95
34	4.201	2.97	2.98	3.01
51	0.000	2.96	2.98	3.01
68	-4.201	3.02	3.00	2.99
85	-8.424	3.01	2.97	2.99
101	-12.462	3.15	3.13	3.11

TABLE 5-9. SMALL COMMUNITY ELEVATION ANTENNA BEAMWIDTHS

BEAM STEP NO.	BEAM ANGLE (Degrees)	BEAMWIDTH (Degrees 5030 MHz	BEAMWIDTH (Degrees) 5060 MHz	BEAMWIDTH (Degrees) 5090 MHz
1	16.763	2.13	2.17	2.17
18	13.830	2.03	2.08	2.15
35	10.942	2.07	2.05	2.05
52	8.097	2.05	2.05	2.06
69	5.275	2.04	2.02	2.03
86	2.469	2.01	2.02	2.03
101	0.000	1.97	1.98	1.99

5.2.3.2.4 Beam Pointing Accuracy Tests - These tests were performed on unfiltered data by positioning the antenna at the desired angle to within ± 0.005 degree. Using the HP 9830 calculator to drive the steering electronics, the beam was stepped past the receiver antenna in a TO-FRO scan and the received amplitudes recorded. Beam pointing accuracy was calculated by curve fitting to find the 3 dB beamwidths and determining the beam centroids with respect to time. Beam timing was assumed as perfect and times between beams determined from look-up tables. Field testing at NAFEC has been shown to correlate well with measured range data.

Figures 5-6 and 5-7 are plots of beam point accuracies of the Basic Narrow and Small Community scanning beam antennas.

5.2.4 Ground Subsystem Test

The ground subsystems, including all monitor poles, interconnect cabling, antennas and electronics, were completely assembled and tested as the last factory test. All monitor limits and equipment adjustments were set up to nominal or specified levels. All monitored functions were exercised by inducing faults that would cause the monitor to alarm or react appropriately. The scan format was completely validated by measuring every radiated function.

As a final test, the ground subsystem radiated signals were evaluated with a Phase III airborne receiver. The receiver decoded the signal format and provided all proper angle and data outputs.

The ground subsystem tests are recorded in the following documents on file in the MLS Program Office:

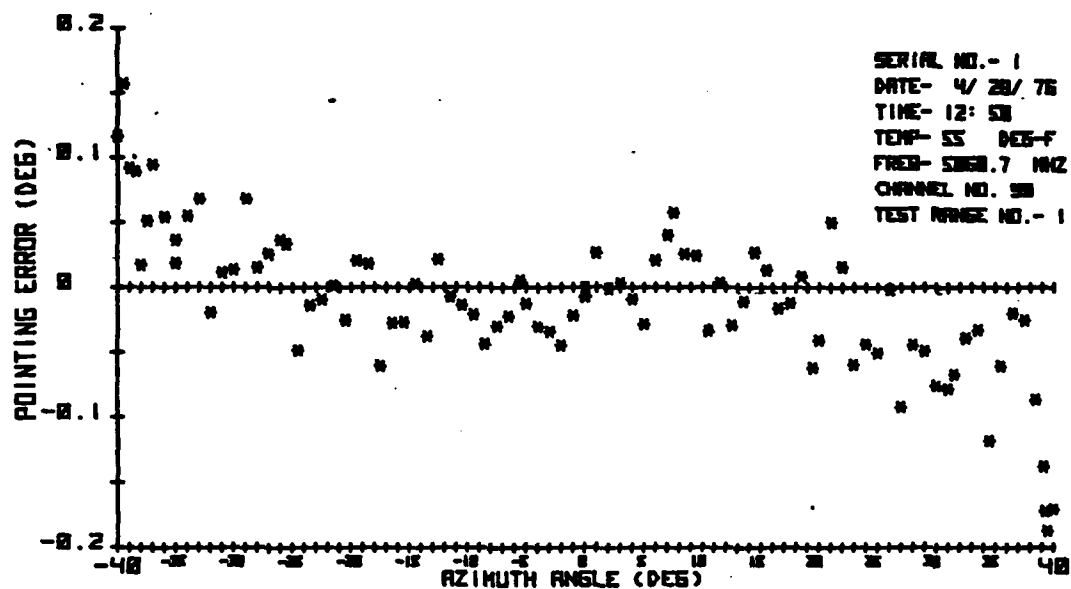


FIGURE 5-6a. DYNAMIC RANGE TEST, BN AZ ANTENNA,
 RAW DATA

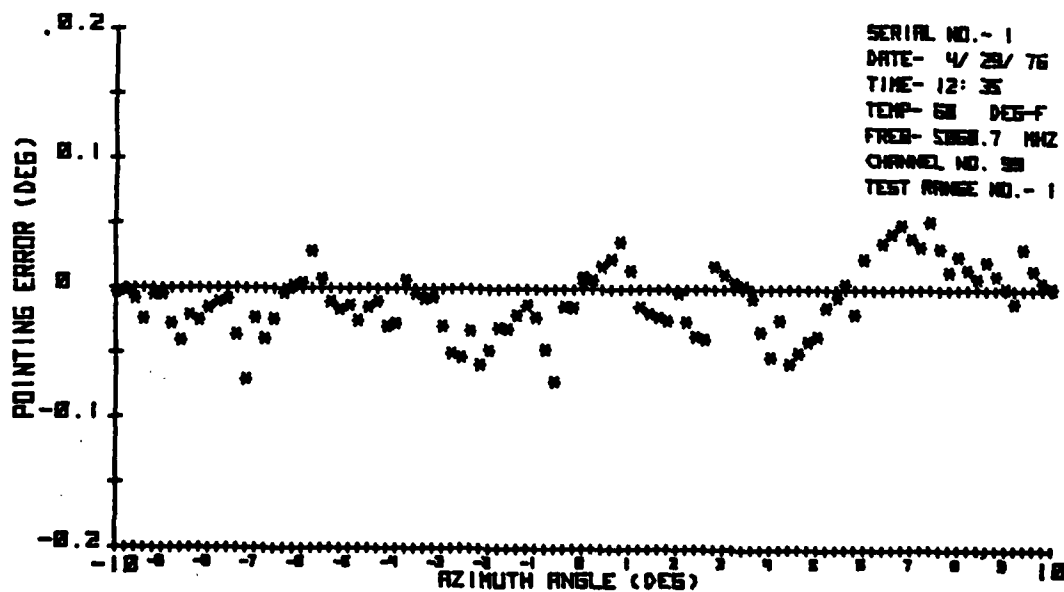


FIGURE 5-6b. DYNAMIC RANGE TEST, BN AZ ANTENNA,
 RAW DATA, EXPANDED SCALE

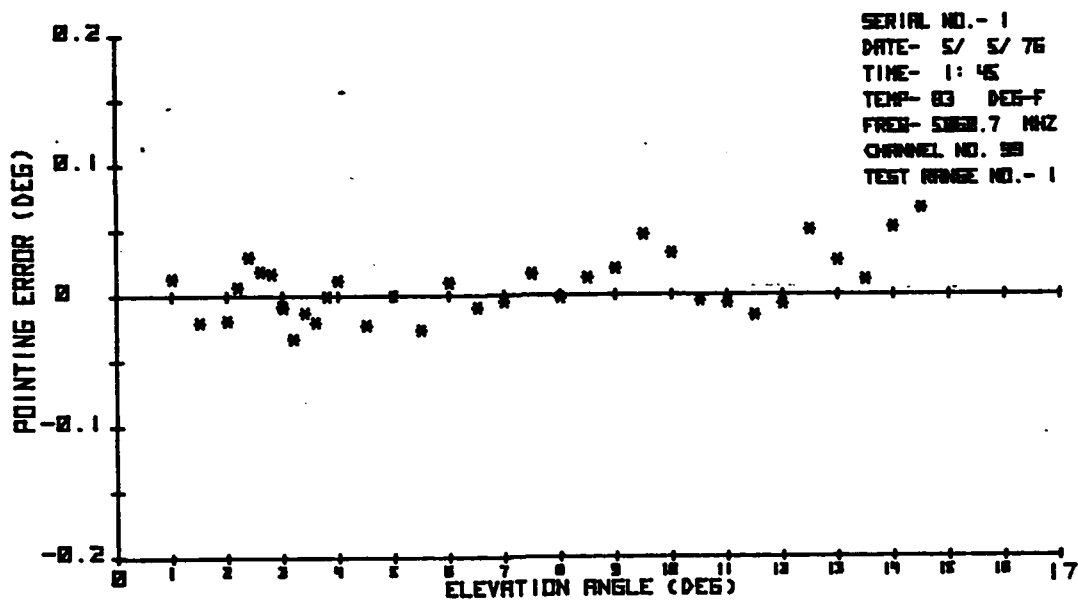


FIGURE 5-6c. DYNAMIC RANGE TEST, BN EL ANTENNA,
 RAW DATA

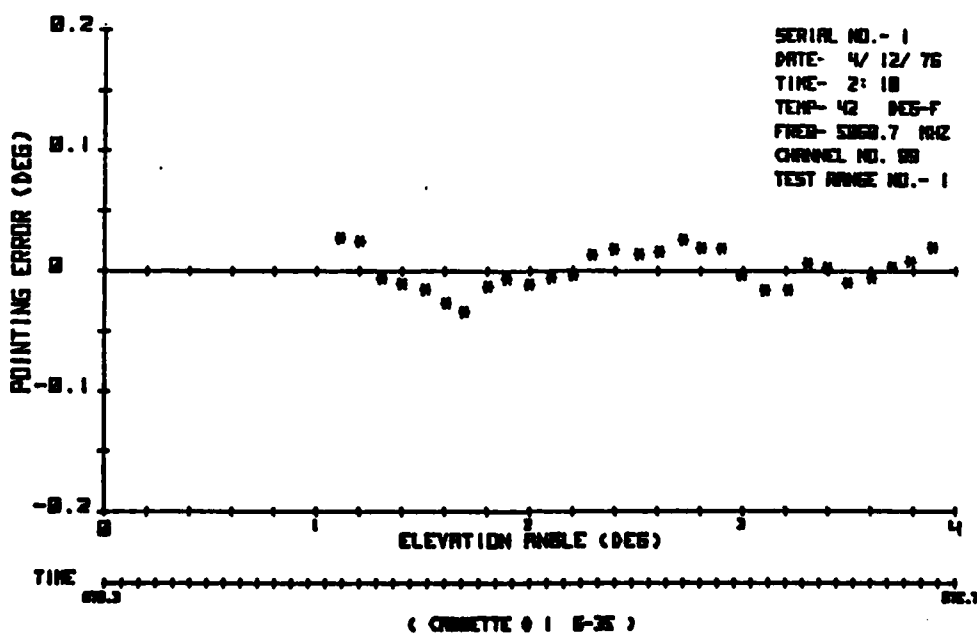


FIGURE 5-6d. DYNAMIC RANGE TEST, BN EL,
 RAW DATA, EXPANDED SCALE

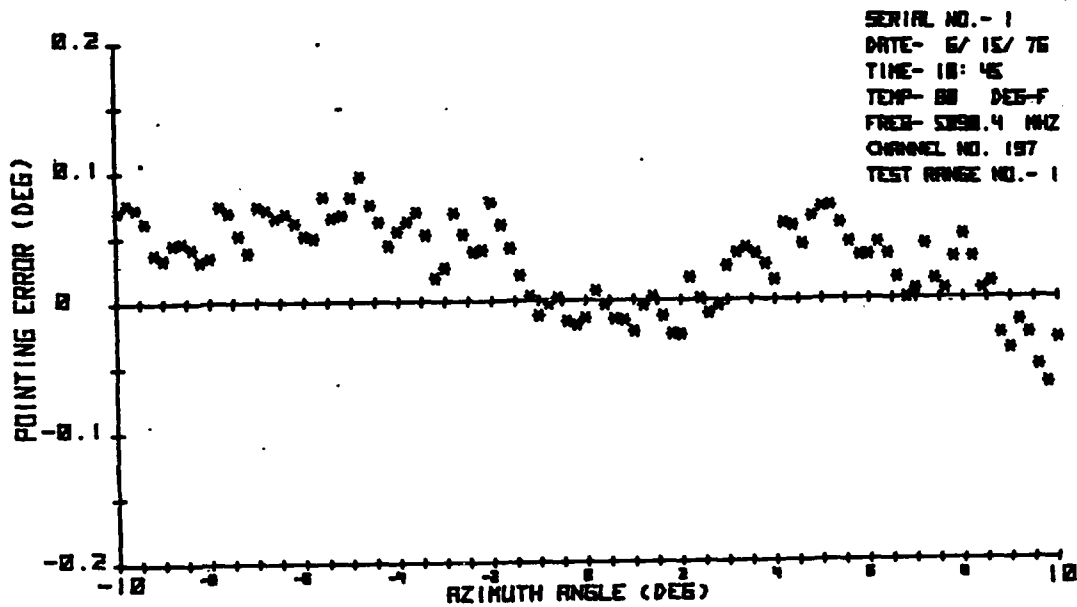


FIGURE 5-7a. DYNAMIC RANGE TEST, SC AZ ANTENNA,
RAW DATA

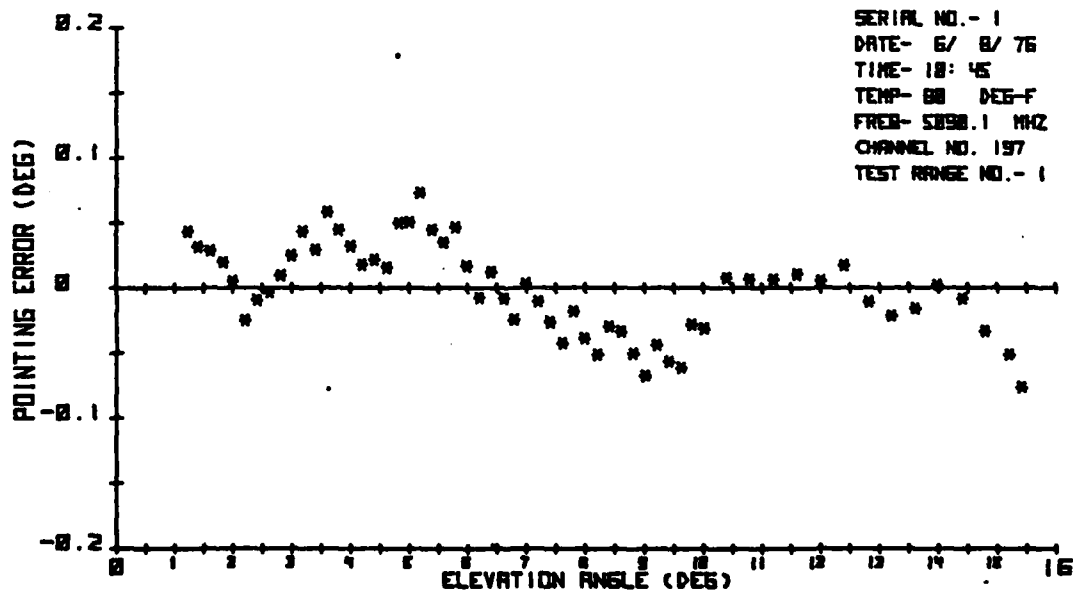


FIGURE 5-7b. DYNAMIC RANGE TEST, SC EL ANTENNA,
RAW DATA

(a) Basic Narrow Azimuth Subsystem	4041035
(b) Basic Narrow Elevation Subsystem	4041036
(c) Small Community Azimuth Subsystem	4041558
(d) Small Community Elevation Subsystem	4041559

5.2.5 Airborne Equipment Tests

The airborne equipment was tested to the same standards and levels as the ground equipments.

5.3 FIELD TESTS

5.3.1 Introduction

The Basic Narrow and Small Community configurations were installed at NAFEC (see Section 6) and subjected to intensive flight and static tests. During the tests, several equipment problems were identified. Although these caused some degradation in accuracy, system accuracy specifications were still met. Some problems were corrected and additional flight tests were conducted; both sets of flight test data are presented in these instances. In the remaining cases, fixes are being designed and evaluated; in these instances, the effects of the equipment faults are identified. Suggested design improvements for future equipments are made in Section 9.

Following the testing at NAFEC, both systems were installed at various airports throughout the world (see paragraph 8.3), and additional flight data collected. Samples of these flight data are included in the following paragraphs.

5.3.2 Basic Narrow Subsystem

Testing of the Basic Narrow subsystem included coverages and accuracies. All data was obtained through a comprehensive series of flight tests utilizing FAA aircraft supported by FAA and Bendix personnel. Due to the mass of data collected, the results of just a few typical tests are reported here to demonstrate that performance meets or exceeds the specifications listed in paragraph 2.2.1. The complete test results are available in the Bendix MLS Project Office or the FAA Program Office.

5.3.2.1 Coverage

5.3.2.1.1 Coverage Requirements - The coverage requirements for the Basic Narrow system are described in paragraph 2.2.1.

5.3.2.1.2 Coverage Performance - Although test data was not collected at NAFEC to measure the angular and range performance of the Basic Narrow configurations, subsequent data collected by the FAA at Kristiansand, Norway, did provide sufficient data to verify the azimuth, elevation, and range coverages. This data includes both orbital and radial flights at constant altitude. No airborne system flags (which would indicate a signal drop out)

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BENDIX CORP. BALTIMORE MD COMMUNICATIONS DIV

F/O 17/7

MICROWAVE LANDING SYSTEM (MLS). PHASE III. (BASIC NARROW & SMAL--ETC(U)

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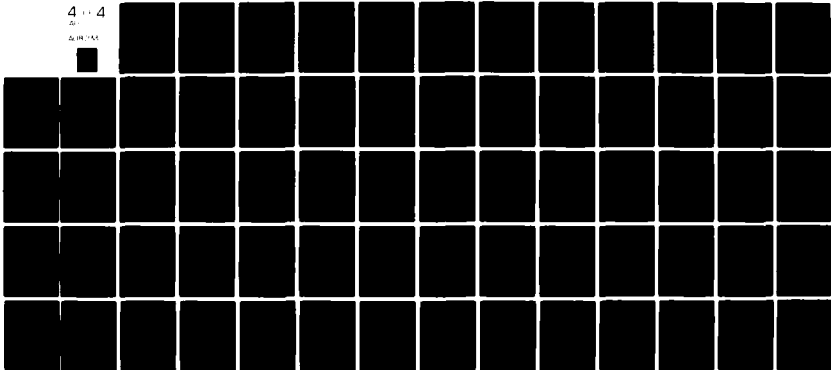
MLS-BCD-R-2801-1-VOL-1

NL

4 1 4

20

20 10 10



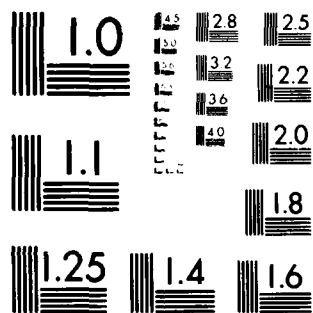
END

DATE

FILED

3 80

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MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

were observed over the defined coverage region. These flights are listed in Table 5-10.

TABLE 5-10, BASIC NARROW SYSTEM COVERAGE TESTS
AT KRISTIANSAND, NORWAY

FLIGHT	START DISTANCE (NM)	ALTITUDE (FT)	AZIMUTH ANGLES OF TEST (DEG)
Orbital	10	3,900	±40
Orbital	10	3,900	±40
Orbital	20	3,100	±40
Orbital	20	10,000	±40
Orbital	20	10,000	±40
Radial	15	2,000	±1
Radial	10	2,000	0
Radial	10	2,000	-1
Radial	10	2,000	-2
Radial	10	2,000	-3

5.3.2.2 Accuracy

5.3.2.2.1 Accuracy Requirements - Table 2-3 shows the 2-sigma error bound requirements for the path following error (PFE) and how the error bounds are increased away from the error window. The minimum guidance altitude above threshold for a Category II performance is 50 feet. The elevation error window for a 2.5-degree glide slope is located 10,610 feet from the Basic Narrow AZ antenna at NAFEC. The glide slope passes through the elevation antenna phase center displaced to runway centerline. The mean of the error data taken over 10-second intervals must be within the 2-sigma path following error bounds.

Table 2-4 presents the 2-sigma error bound requirements on control motion noise (CMN) and how these bounds are degraded linearly for distances greater than the error window. Ninety-five percent of the error data taken over a 10-second interval must be within the control motion noise bounds. In other words, twice the standard deviation (2 sigma) of the error data must not exceed the CMN error bounds.

5.3.2.2.2 Error Data - Figures 5-8a through 5-9b show the Basic Narrow azimuth and elevation error performance for centerline flight tests on a 3-degree glide slope at the outputs of the path following and control motion filters specified in FAA-ER-

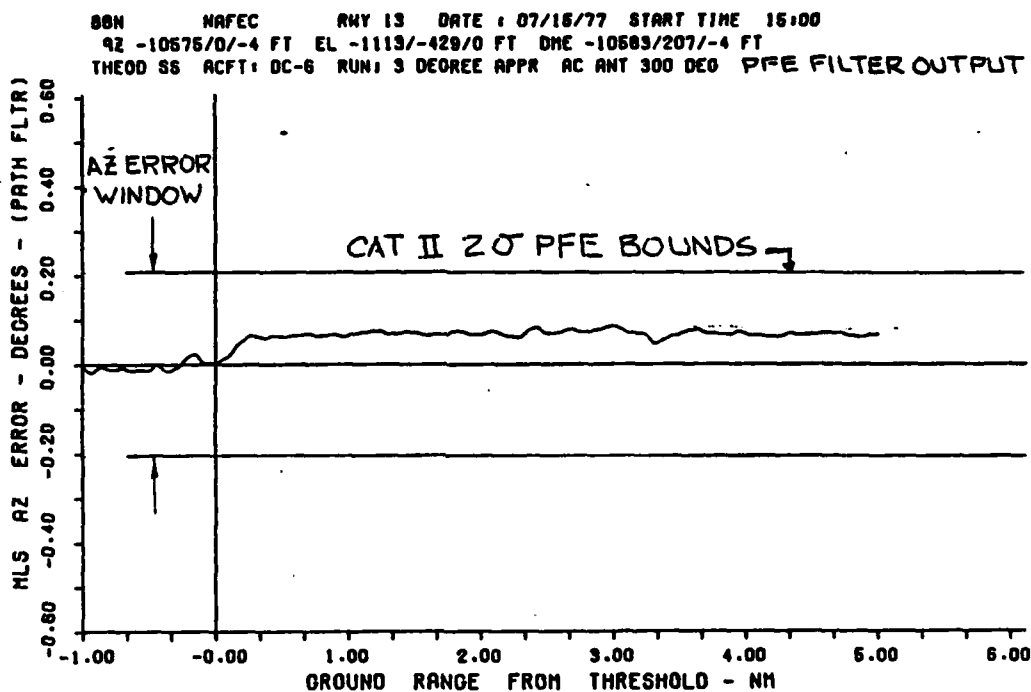


FIGURE 5-8a. BASIC NARROW AZ ANTENNA, PFE FOR 3° GLIDESLOPE

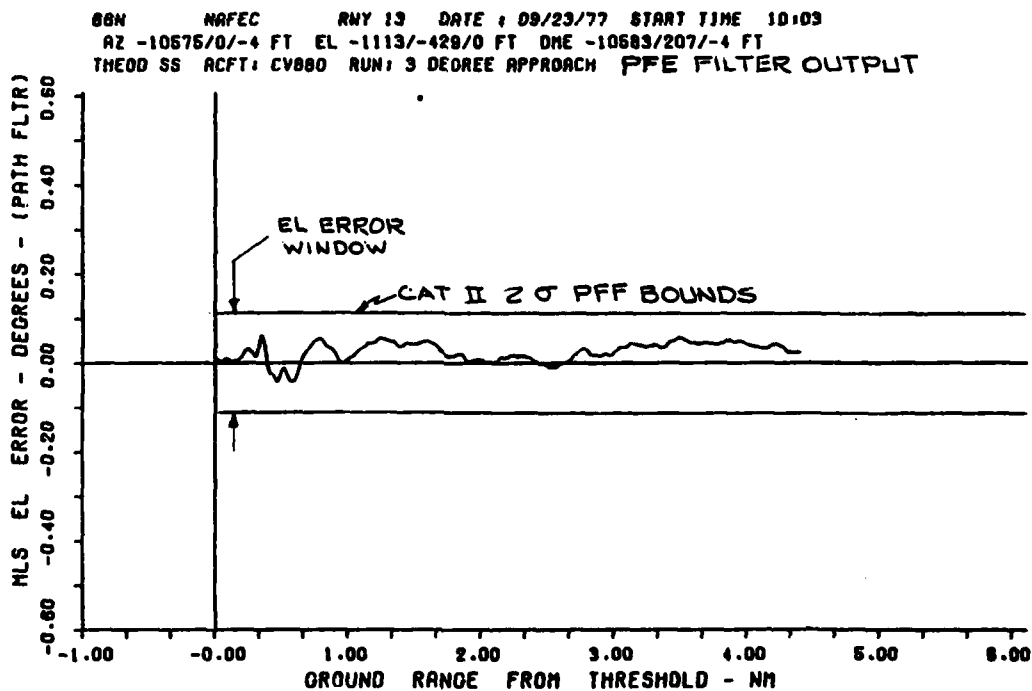


FIGURE 5-8b. BASIC NARROW EL ANTENNA, PFE FOR 3° GLIDESLOPE

BBN NAFEC RMY 13 DATE : 07/16/77 START TIME 15:00
 AZ -10576/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
 THEOD SS ACFT: DC-6 RUN: 3 DEGREE APPR AC ANT 300 DEG CMN FILTER OUTPUT

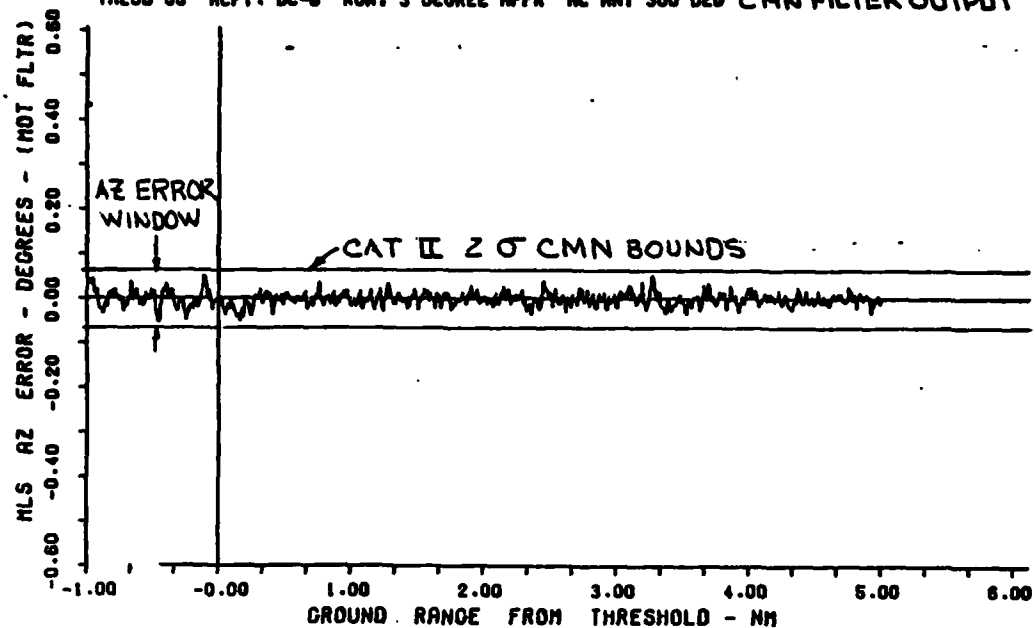


FIGURE 5-9a. BASIC NARROW AZ ANTENNA, CMN FOR 3° GLIDESLOPE

BBN NAFEC RMY 13 DATE : 09/23/77 START TIME 10:03
 AZ -10576/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
 THEOD SS ACFT: CV880 RUN: 3 DEGREE APPROACH CMN FILTER OUTPUT

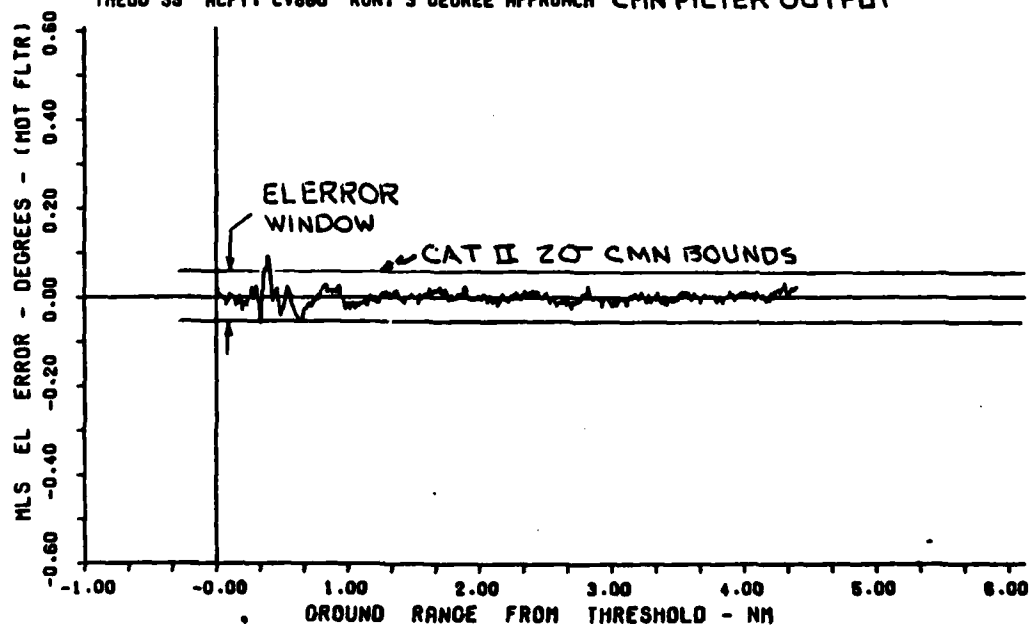


FIGURE 5-9b. BASIC NARROW EL ANTENNA, CMN FOR 3° GLIDESLOPE

700-07. Also shown are the Category II 2-sigma error bounds specified in Tables 2-3 and 2-4. The significant factor is that the 2-sigma lateral and vertical path following errors do not exceed the specified 28-foot and 2.2-foot errors when the aircraft altitude is 50 feet. The path following error requirement is clearly satisfied since all points fall within the path following error bounds.

The control motion noise requirement is that the AZ and EL 2-sigma errors be less than 0.065 and 0.05 degree, respectively, or equivalently, that 95 percent of the points measured in a 10-second interval must be within these bounds. The control motion noise requirement is clearly satisfied as shown by Figures 5-9a and 5-9b.

5.3.2.2.3 Statistical Error Data - Table 5-11 shows the cumulative mean and 2-sigma path following errors for single runs of selected flight data. The cumulative errors are the averages over the entire flight of the mean and 2-sigma errors for each 10-second interval. The coverage over which the errors were obtained is also shown.

TABLE 5-11. BASIC NARROW STATISTICAL DATA
(PFE FILTER OUTPUT)

FLIGHT	SUBSYSTEM	COVERAGE (a)	CUMULATIVE MEAN ERROR (b)	CUMULATIVE 2 σ ERROR (b)
3° CENTERLINE APPROACH	AZ	4.4 nmi to -1.0 nmi	0.068°	0.027°
	EL	4.4 nmi to 0.1 nmi	0.025°	0.024°
2000' CENTER LINE OVERFLIGHT	AZ	4.1 nmi to -1.0 nmi	0.066°	0.024°
	EL	4.1 nmi to 1.0 nmi	0.012°	0.016°
5 NMI ORBIT AT 2000'	AZ	-40.8° to 41.6°	0.069°	0.067°
	EL	-40.9° to 41.7°	0.019°	0.021°

NOTES:

- (a) Ground range from threshold or azimuth angle.
- (b) Average of mean and 2-sigma errors for all 10-second data intervals over entire run.

The mean error over 10 seconds of flight must be less than the 2-sigma PFE bounds. For the Basic Narrow system, the 2-sigma PFE autoland specification at the error window in a 3-degree glidepath, given in document FAA-ER-700-07, Specification Change 8, dated 12/13/76, adjusted for runway threshold at NAFEC (10,580 feet from AZ) is 0.073 degree in azimuth and 0.11 degree in elevation. The mean error over each coverage interval in Table 5-11 is within the bounds in all cases.

The 2-sigma error over 10-second flight intervals must be less than the 2-sigma path following noise specifications. The worst-case autoland noise specification is 0.04 degree in azimuth and 0.05 degree in elevation. Table 5-11 shows that the cumulative 2-sigma errors for both functions clearly fall within these limits, except for the 5-nmi orbital flight in azimuth.

5.3.2.3 Autoland Capability - Since a design goal was Category III (autoland performance), it is informative to compare actual flight data with this goal. To show accuracy performance for automatic landings, both static test data and flight data will be evaluated.

5.3.2.3.1 Autoland Accuracy Requirements - Table 5-12 shows the azimuth 2-sigma path following error bounds of 0.073° (13.5 ft) at the NAFEC error window (10,580 ft. from AZ for azimuth, 50 ft. altitude on 3-degree glide path for elevation). The elevation bound at the error window is 0.11 degree (1.8 feet). Inside the error window, the Category III performance requirements remain at the 13.5-foot lateral and 1.8-foot vertical error limit.

Table 5-13 gives the 2-sigma error bounds on control motion noise for autoland performance.

5.3.2.3.2 Static Data - Figure 5-10 is an azimuth static test with the van located near the threshold of runway 13/31. Also shown is the 2-sigma PFE autoland (CAT III) bound. Figure 5-10 shows that the mean of the azimuth errors is within the error bounds for all heights, thus demonstrating autoland performance. The control motion noise specification is 0.04 degree at threshold. Hence, the separation between the 2.5 and 97.5 percentile points can be as large as 0.08 degree. This is clearly satisfied by the points listed in the figure.

Figure 5-11 represents a static test of the elevation errors about 300 feet from runway threshold. The autoland PFE specification is satisfied down to a pole height of 14 feet above the runway surface since the mean of the errors is within the 2-sigma PFE bounds. The CMN autoland specification is also satisfied since the greatest separation between 1-sigma bars is 0.04 degree. Since this is less than the 0.05-degree CMN specification, the autoland requirement is satisfied.

TABLE 5-12. PATH FOLLOWING ERROR SPEC AT NAFEC ERROR WINDOW
TYPE 3 EQUIPMENT

ANTENNA SIGNAL	PFE (2 σ)		DISTANCE TO ERROR WINDOW (FT)	PFE DEGRADATION (a)		
	FT.	DEG.		IN RANGE	IN AZIMUTH	IN ELEVATION
AZIMUTH	13.5	0.073	10580 (b)	Linear to 0.16° at 20 nmi	2:1 in angle from 0° at $\pm 60^\circ$	2:1 in angle from 9° to 20°
ELEVATION	1.8	0.11	938 (c)	1.5:1 in angle at 20 nmi	None	3:1 in angle from 2° to 20°

(a) Degradations vary linearly between limits indicated.

(b) Distance ground range from A2 antenna.

(c) Distance slant range from EL phase center.

TABLE 5-13. CONTROL MOTION NOISE SPECIFICATION,
TYPE 3 EQUIPMENT

ANTENNA SIGNAL	NOISE (2 σ)	ALLOWABLE DEGRADATION		
		WITH DISTANCE	WITH AZIMUTH ANGLE	WITH ELEVATION ANGLE
Azimuth	0.04°	1.4:1 at 20 nmi	None	None
Elevation	0.05°	1.4:1 at 20 nmi	None	None

- MEAN AND S/D
- * 2.5 AND 97.5 PERCENTILES

TEST NO.: 1
DATE: 1/ 25/ 77
TIME: 1650

SURVEY PT. = 44 X = 10458.46 Y = -8.81 Z = 4.13

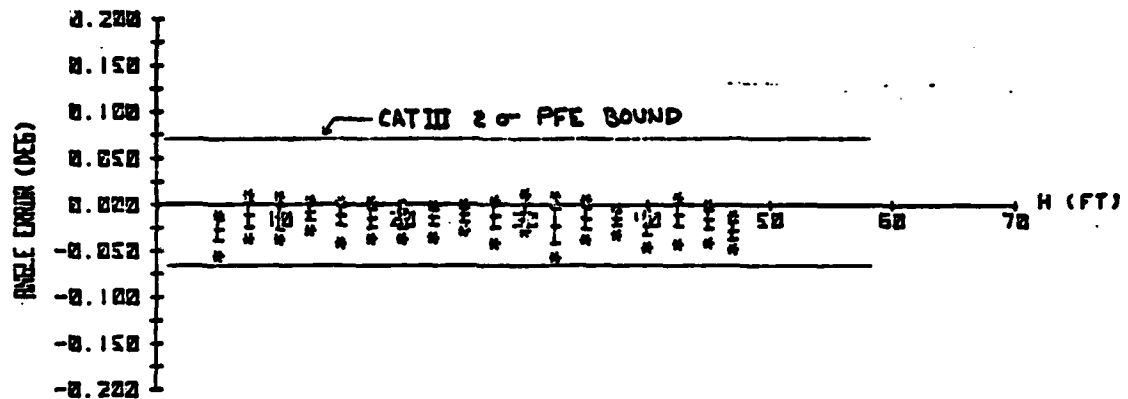


FIGURE 5-10. BASIC NARROW AZ ANTENNA, STATIC TEST RUNWAY CENTERLINE

- MEAN AND S/D
- * 2.5 AND 97.5 PERCENTILES

TEST NO.: 18
DATE: 8/ 8/ 77
TIME: 903

SURVEY PT. = 45 X = 10258.46 Y = 0 Z = 3.61

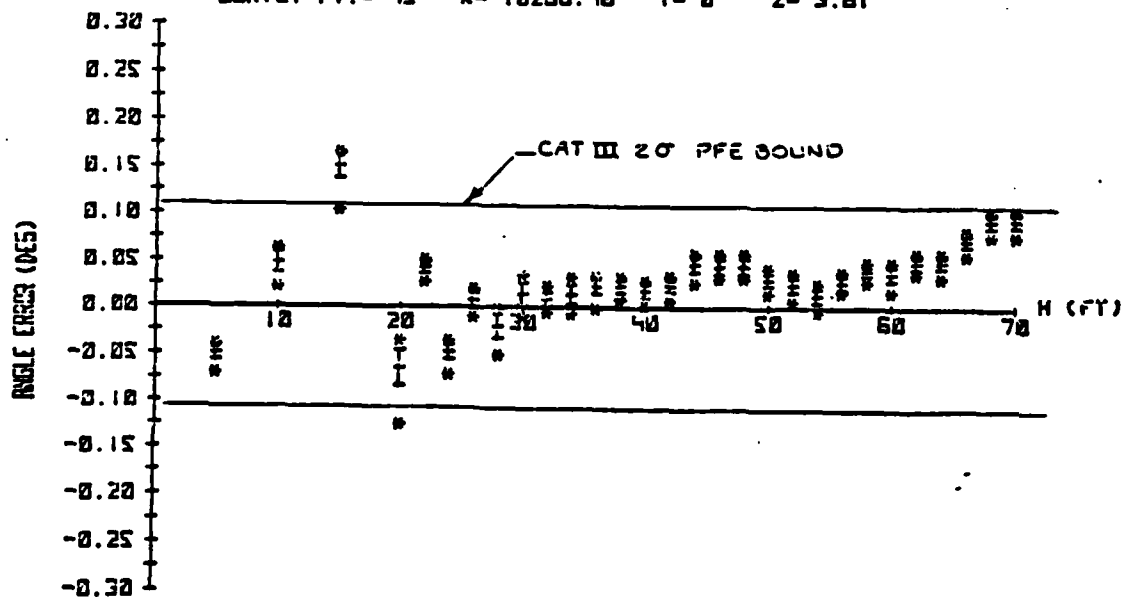


FIGURE 5-11. BASIC NARROW EL ANTENNA, STATIC TEST RUNWAY CENTERLINE

5.3.2.3.3 Flight Data - Figures 5-12a through 5-13b show that the Basic Narrow system satisfies the autoland requirement for a centerline approach along a 3-degree glide path. Realignment of the azimuth antenna would reduce the azimuth PFE term in Figure 5-12a to within the ± 0.073 degree specification. The elevation PFE and azimuth and elevation CMN are all within the allowable 2-sigma limits as defined above.

5.3.2.4 Problems - The most significant problems which occurred during the Basic Narrow test program are discussed. Test results obtained after corrective action was taken are included to illustrate the effectiveness of the corrections.

5.3.2.4.1 Azimuth Radome - An accumulation of water and/or ice within the azimuth antenna radome caused small but identifiable beam pointing errors at an azimuth vertical coverage angle of approximately 3.5 degrees. This error is clearly illustrated by Figure 5-14. This problem was alleviated by the installation of a new radome as illustrated by the raw data plot in Figure 5-16.

5.3.2.4.2 Bent Azimuth Vertical Aperture - Once the radome problem, mentioned above, was eliminated, it was clear that a second problem existed in the BN AZ. This problem caused azimuth guidance bias errors at vertical coverages above 4-degree angles as illustrated by Figure 5-15. This problem was eventually traced to a curved aperture on the BN AZ antenna. When the aperture was straightened, the bias error was greatly reduced. Figure 5-16 illustrates the combined improvement resulting from the new radome and straightened aperture.

5.3.2.4.3 Elevation Sloping Bias Error - On 5-nmi orbital flights at 2000 feet altitude, a sloping bias of 0.0125 degree error/10 degree change of azimuth occurred in BN EL data (Figure 5-17). The problem was diagnosed as distorted dipole ground plane. Figure 5-18 illustrates the improvement when this problem was corrected.

5.3.2.4.4 Monitor Horn Interface - Diffraction of the scanning beam by the monitor horn and pole causes distortion of the beam and errors near centerline. The oscillating error about the 0-degree azimuth angle in Figure 5-17 is due to this interference. Two techniques which can be used to reduce this interference are to lower the monitor horn or replace the pole and horn with an antenna and support of reduced cross section. Both techniques are being evaluated (see paragraph 9.2.3).

5.3.2.5 Summary of Basic Narrow Field Test Results - It has been demonstrated through static and dynamic testing that the Basic Narrow system meets or exceeds all accuracy requirements, over the full coverage, for Category II operation. Additionally, it has been shown that the Basic Narrow system meets the Category III (autoland) requirements, which are comparable to the AWOP full capability requirements. Four problems which affected the error performance were identified during the NAFEC

BBN NAFEC RMY 13 DATE : 07/16/77 START TIME 16:00
 AZ -10575/0/-4 FT EL -1113/-429/0 FT ONE -10583/207/-4 FT
 THEOD 88 ACFT: DC-8 RUN: 3 DEGREE APPR AC ANT 300 DEG PFE FILTER OUTPUT

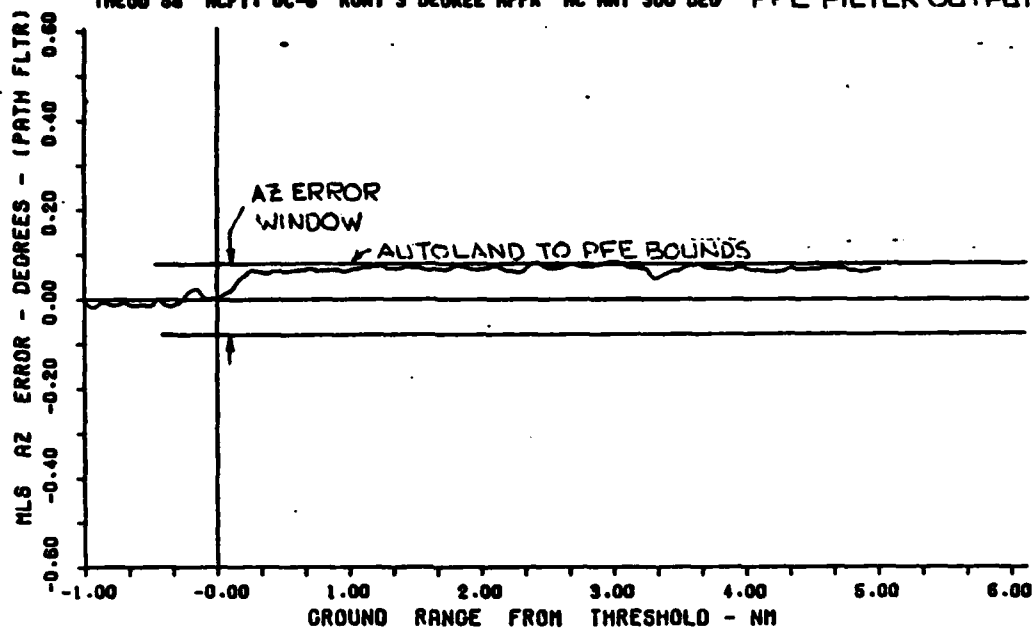


FIGURE 5-12a. BASIC NARROW AZ ANTENNA, PFE FOR 3° GLIDESLOPE

BBN NAFEC RMY 13 DATE : 08/23/77 START TIME 10:03
 AZ -10575/0/-4 FT EL -1113/-429/0 FT ONE -10583/207/-4 FT
 THEOD 88 ACFT: CV880 RUN: 3 DEGREE APPROACH PFE FILTER OUTPUT

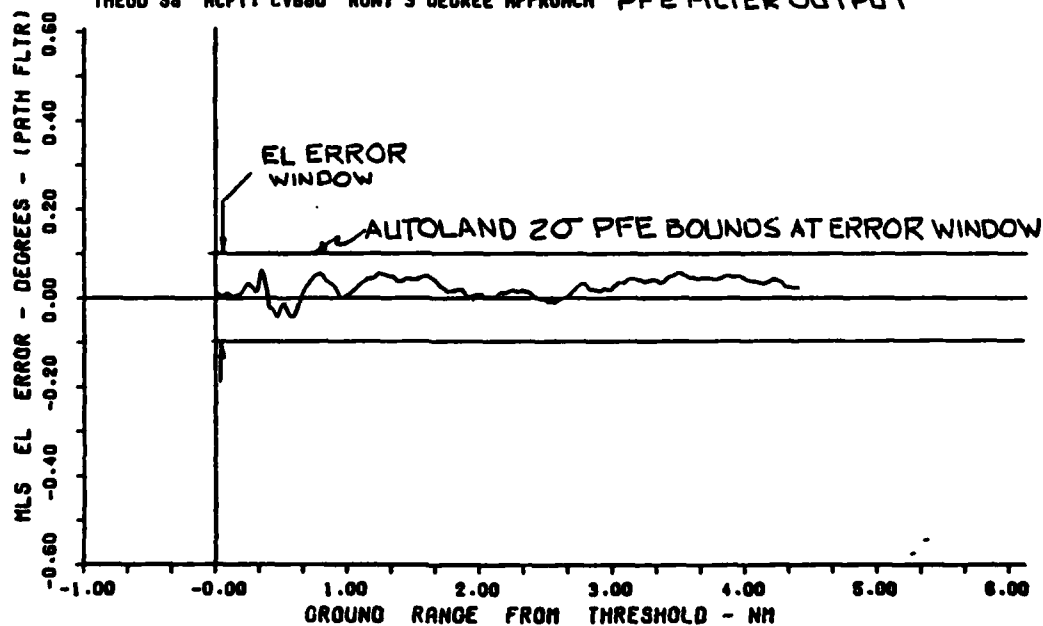


FIGURE 5-12b. BASIC NARROW EL ANTENNA, PFE FOR 3° GLIDESLOPE

BBN NAFEC RMY 13 DATE : 07/15/77 START TIME 16:00
 AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
 THEOD SS ACFT: DC-6 RUN: 3 DEGREE APPR AC ANT 300 DEG CMN FILTER OUTPUT

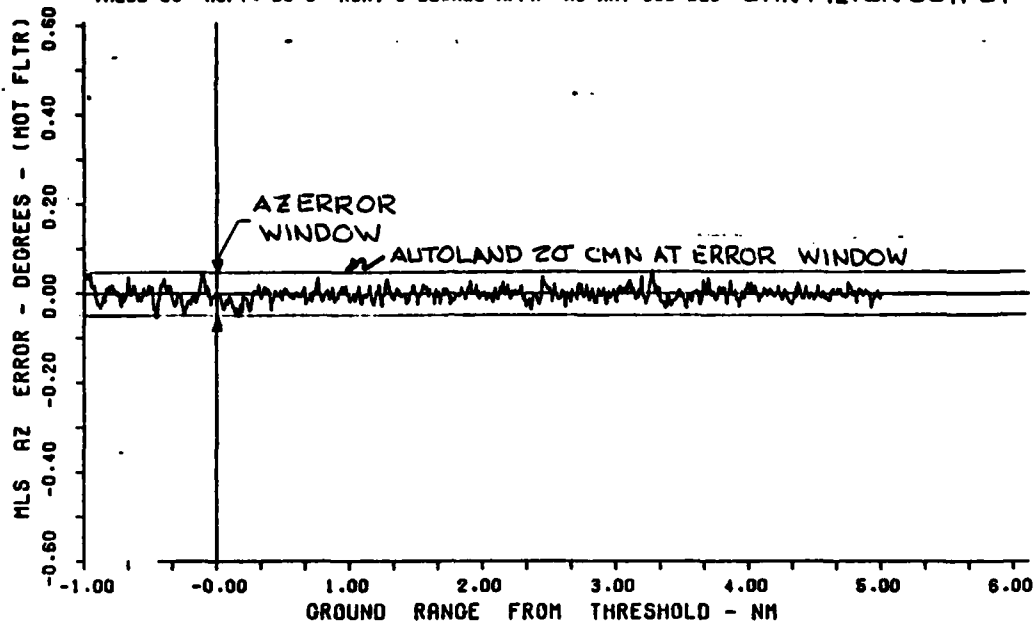


FIGURE 5-13a. BASIC NARROW AZ ANTENNA, CMN FOR 3° GLIDESLOPE

BBN NAFEC RMY 13 DATE : 09/23/77 START TIME 10:03
 AZ -10575/0/-4 FT EL -1113/-429/0 FT DME -10583/207/-4 FT
 THEOD SS ACFT: CV880 RUN: 3 DEGREE APPROACH CMN FILTER OUTPUT

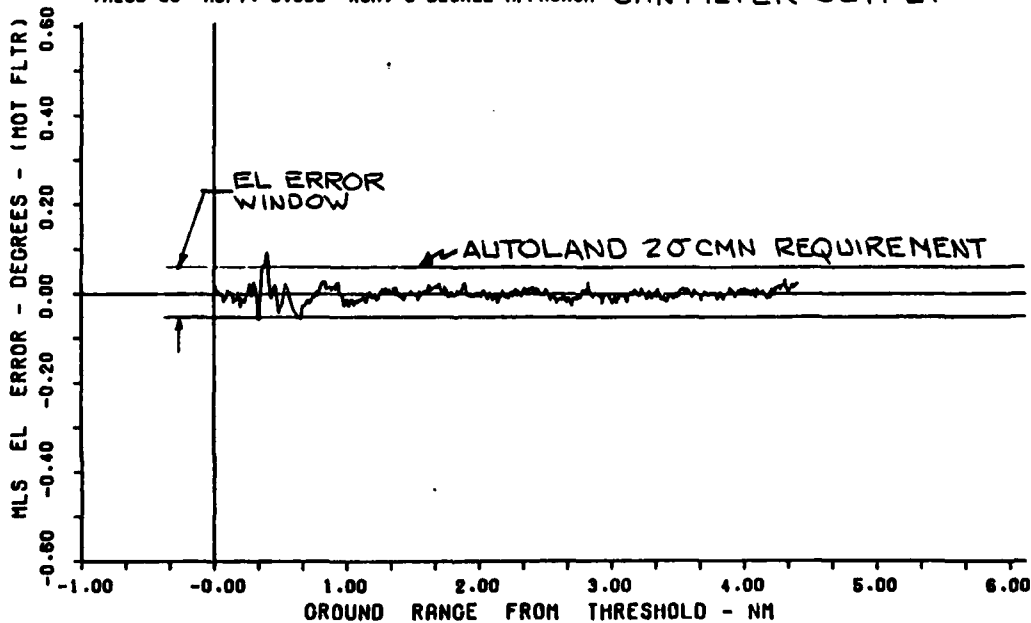


FIGURE 5-13b. BASIC NARROW EL ANTENNA, CMN FOR 3° GLIDESLOPE

OCT 4. 1976 THEO ONLY 1450 HRS AZ
 BASIC NARROW AZ
 2000 FT ALT CENTERLINE

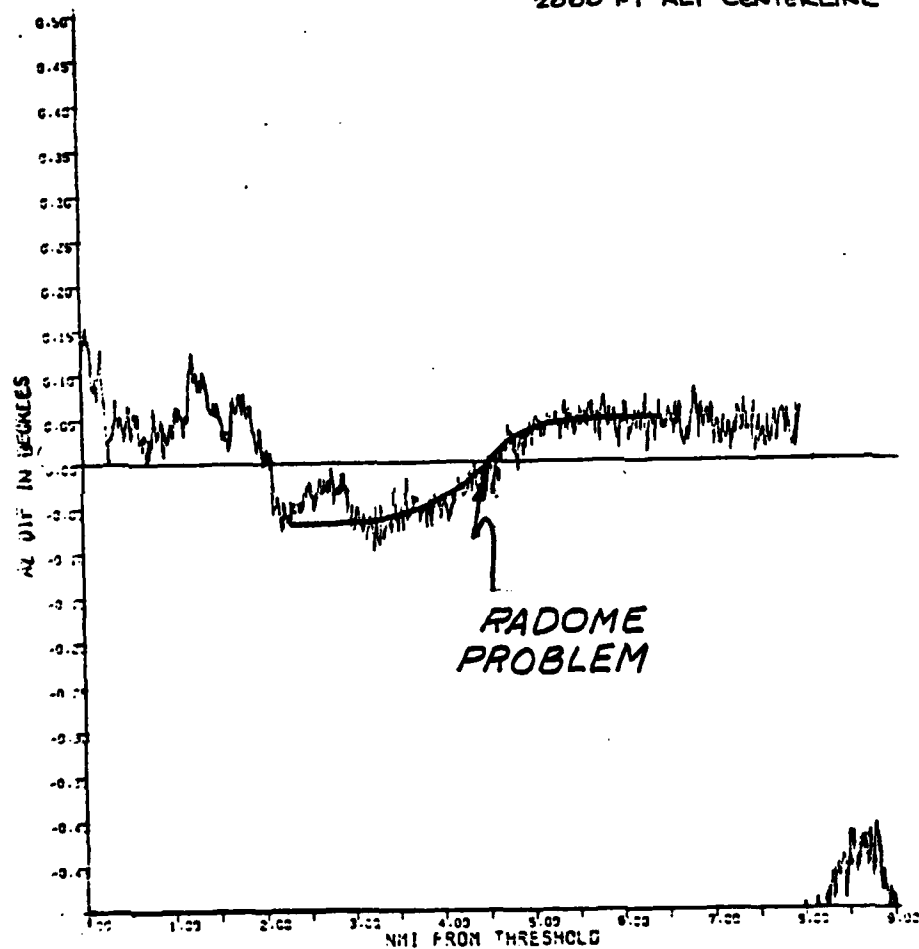


FIGURE 5-14. BASIC NARROW AZ ANTENNA, RAW DATA ERROR
 PLOT WITH FAULTY RADOME

3/14/77 BN10 RUN 04 1443 HRS SYS 1 AZ
 14 56 HRS
 BN-AZ ζ RADIAL 2000FT. ALT.

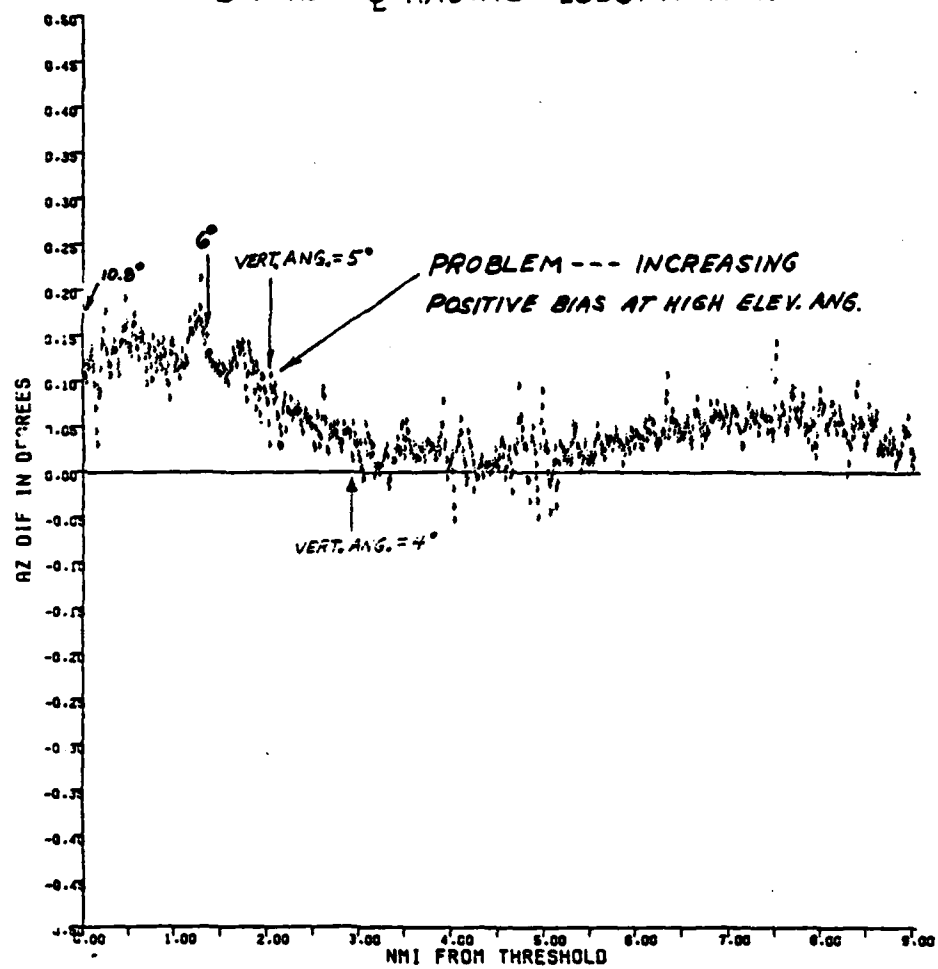


FIGURE 5-15. BASIC NARROW AZ ANTENNA, RAW DATA ERROR PLOT WITH DISTORTED APERTURE

BBN HAFEC RMY 13 DATE : 07/16/77 START TIME 14:50
 AZ -10575/0/-4 FT EL -1113/-429/0 FT ONE -10583/207/-4 FT
 THEOD SS ACFT: DC-8 RUN: 0 DEG RADIAL 2K FT AC ANT 300 DEG

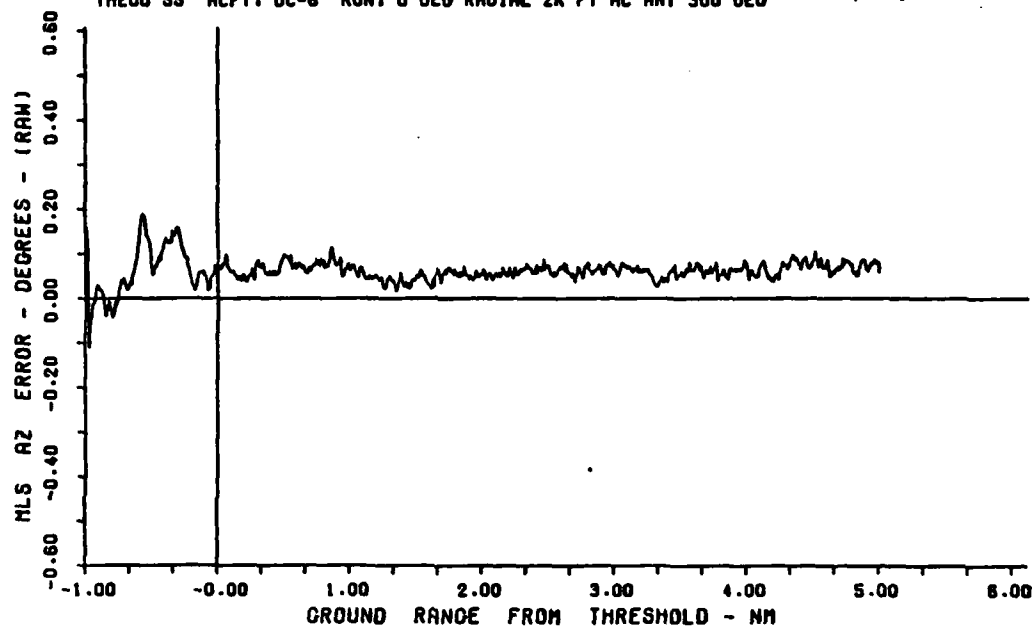


FIGURE 5-16, BASIC NARROW AZ ANTENNA, RAW DATA ERROR PLOT AFTER REPLACING FAULTY RADOME AND CORRECTING DISTORTED APERTURE

SEPT 24, 1976 PHASE 3 TEST EL-ORBIT 1553

CUJ 2000' 5 NMI

RCUR 102

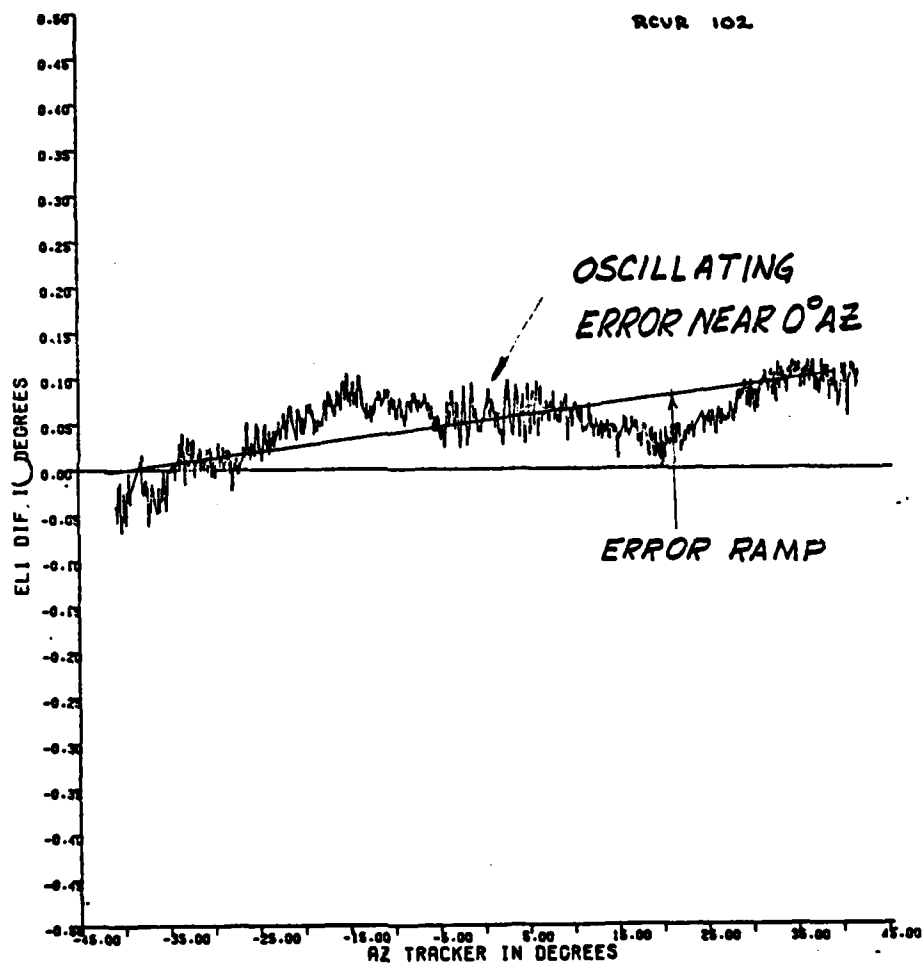


FIGURE 5-17. BASIC NARROW EL ANTENNA, RAW DATA ERROR
PLOT WITH DISTORTED APERTURE

BBN NAFEC RMY 13 DATE : 09/01/77 START TIME 13:38
 AZ -10676/0/-4 FT EL -1113/-429/0 FT ONE -10683/207/-4 FT
 THEOD SS ACFT: OC-6 RUN: ORBIT 2N FT AT 5 NM AC ANT OMNI

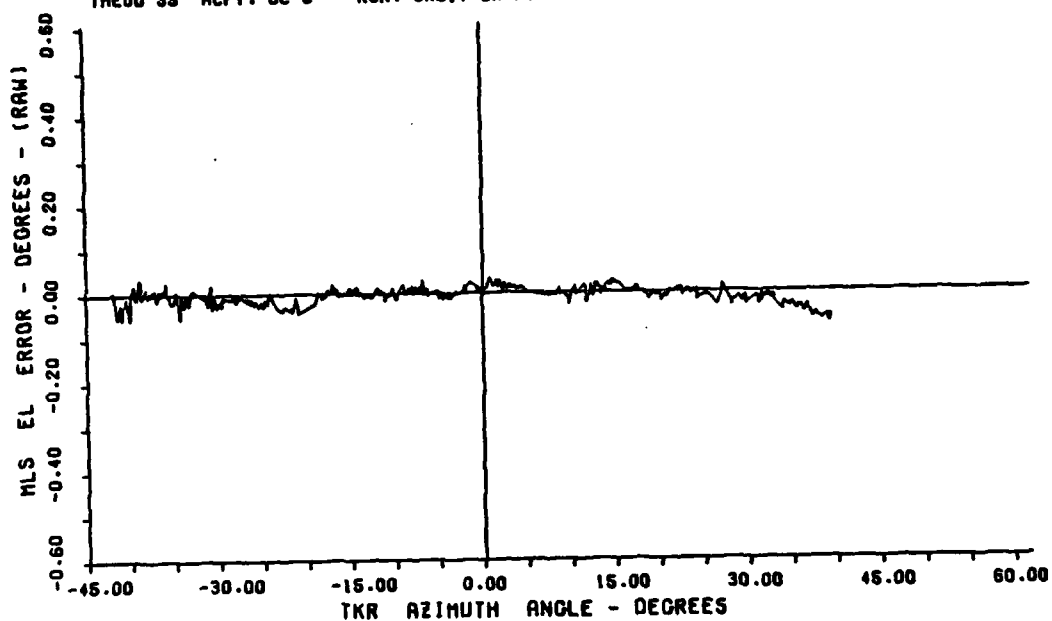


FIGURE 5-18. BASIC NARROW EL ANTENNA, RAW DATA ERROR
 PLOT AFTER CORRECTING DISTORTED APERTURE

tests, and corrective actions were taken on three of these problems. A solution to the fourth problem (scattering by the monitor antenna pole) is being evaluated.

5.3.3 Small Community Subsystem

Testing of the Small Community Subsystem included coverage, accuracy, and autoland performance. All data was obtained through a comprehensive series of flight tests utilizing FAA aircraft supported by FAA and Bendix personnel. Due to the mass of data collected, the results of just a few typical tests are reported here to demonstrate that performance meets or exceeds the specifications listed in paragraph 2.2.2. The complete test results are available in the Bendix MLS Project Office and the FAA Program Office.

5.3.3.1 Coverage

5.3.3.1.1 Coverage Requirements - Coverage requirements for the Small Community system are described in paragraph 2.2.2.

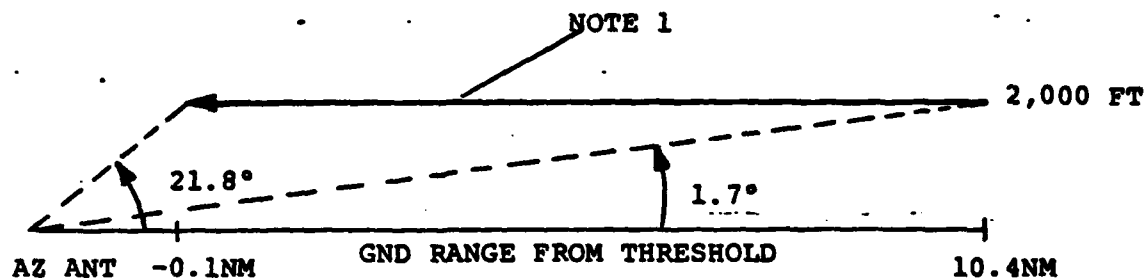
5.3.3.1.2 Coverage Performance - Coverage performance was demonstrated by a series of orbital and radial flights.

Figures 5-19 through 5-22 show representations of flights by solid, heavy lines with an arrow at the end. Each flight path indicating coverage is tagged with a footnote which gives detailed flight log information on the runs used to provide the coverage data.

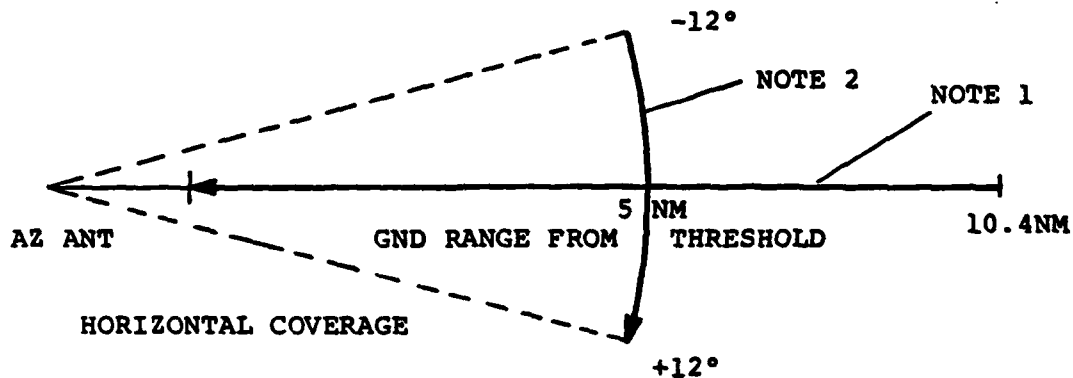
- (a) AZ Subsystem - Figure 5-19 shows the vertical and horizontal coverage for the Small Community AZ system obtained from a 2000-foot altitude centerline overflight and a 2000-foot altitude 5-nmi orbit. This figure shows that the required -10 degrees to +10 degrees azimuth proportional coverage is provided at 5 nmi. The vertical coverage exceeds the required 15 degrees (see Figure 2-3).

The lower vertical angle coverage requirement of 1 degree is satisfied by the 10,000-foot altitude overflight represented by Figure 5-20. Azimuth proportional guidance coverage between -10 degrees to +10 degrees is shown at 20-nmi range. The 91-nmi range, where data collection started, is almost six times greater than the 15.7 nmi requirement. Coverage to 10,000-foot altitude is also illustrated.

Flight performance has verified that fly-left/fly-right sector guidance information is supplied from the azimuth limits of proportional guidance out to ± 40 degrees from runway centerline.



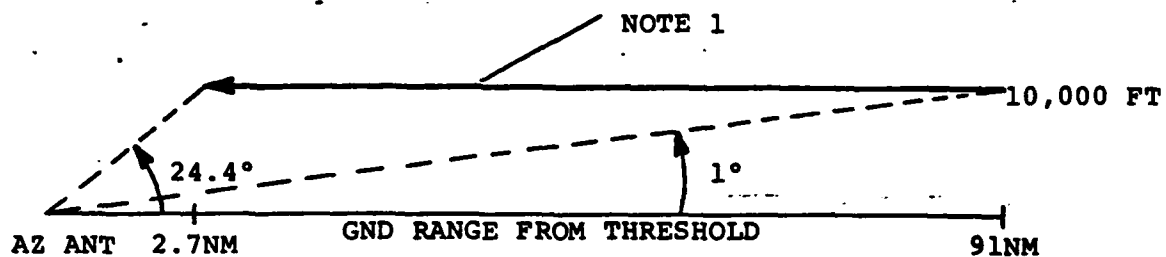
VERTICAL COVERAGE



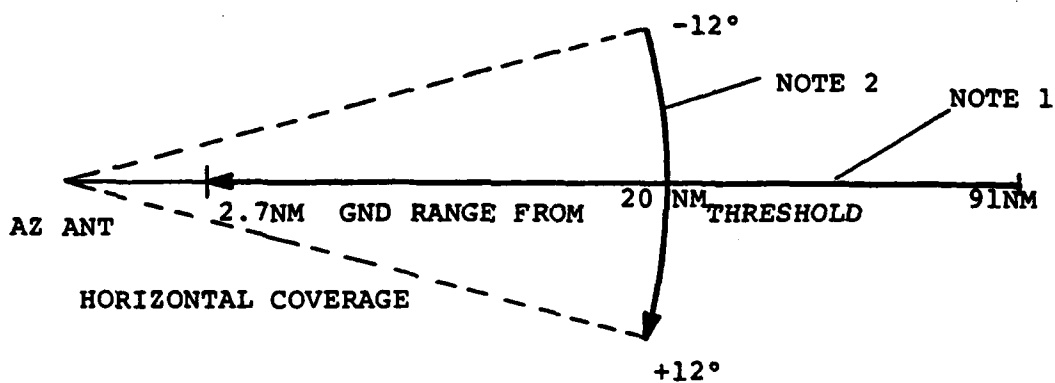
NOTE 1. 2,000 FT. ALT C_L OVERFLIGHT 10/27/76 FLIGHT SC #1
 RUN #6 SYSTEM 1 TRACKER THEODOLITE

NOTE 2. 2,000 FT. ALT. 5NM CW ORBIT 4/22/77 FLIGHT SC #12
 RUN #6 SYSTEM 1 TRACKER THEODOLITE

FIGURE 5-19. SMALL COMMUNITY AZ 2,000 FT ALTITUDE COVERAGE FLIGHT DATA



VERTICAL COVERAGE

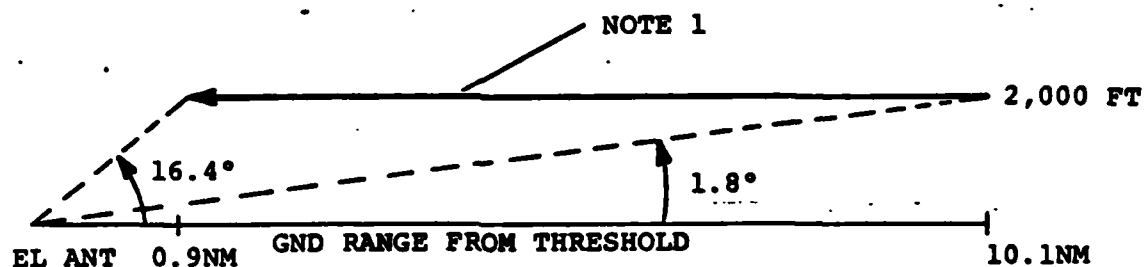


HORIZONTAL COVERAGE

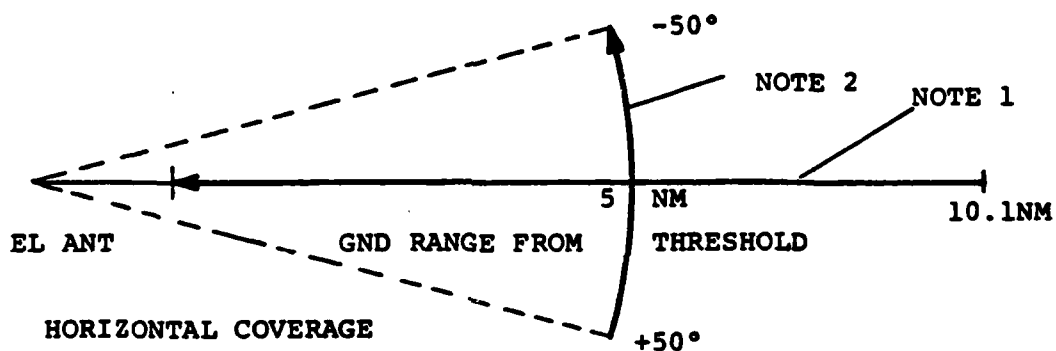
NOTE 1. 10,000 FT. ALT. C_L OVERFLIGHT 4/8/77 FLIGHT SC #6
 RUN #4 SYSTEM 2 TRACKER EAIR

NOTE 2. 10,000 FT. CW ORBIT 4/8/77 FLIGHT SC #6 RUN #1
 SYSTEM 1 TRACKER EAIR

FIGURE 5-20. SMALL COMMUNITY AZ 10,000 FT. ALTITUDE COVERAGE
 FLIGHT DATA



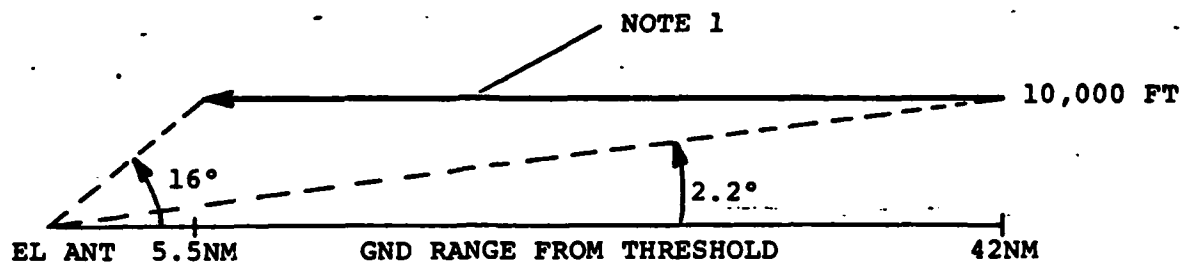
VERTICAL COVERAGE



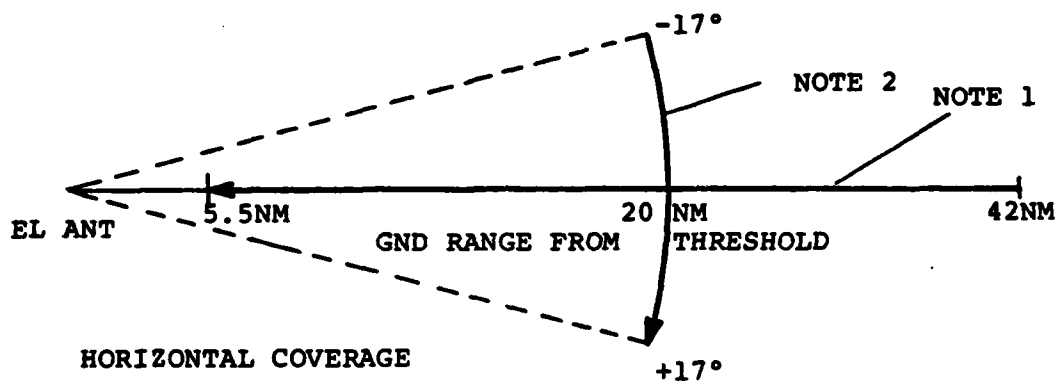
NOTE 1. 2,000 FT ALT C_L OVERFLIGHT 4/1/77 FLIGHT SC #3 RUN #5
SYSTEM 1 THEODOLITE TRACKER.

NOTE 2. 2,000 FT ALT 5NM CCW ORBIT 4/22/77 FLIGHT SC #12
RUN #5 SYSTEM 1 EAIR TRACKER.

FIGURE 5-21. SMALL COMMUNITY EL 2,000 FT. ALTITUDE COVERAGE
FLIGHT DATA



VERTICAL COVERAGE



HORIZONTAL COVERAGE

NOTE 1. 10,000 FT. ALT. C_L OVERFLIGHT 4/8/77 FLIGHT SC #6

RUN #4 SYSTEM 2 EAIR TRACKER

NOTE 2. 10,000 FT. ALT. CW ORBIT 4/8/77 FLIGHT SC #6

RUN #1 SYSTEM 1 EAIR TRACKER

FIGURE 5-22. SMALL COMMUNITY EL 10,000 FT. ALTITUDE COVERAGE FLIGHT DATA

- (b) EL Subsystem Coverage - Vertical proportional guidance coverage from 1.8 degree to greater than 15 degrees is shown in Figure 5-21. Static tests show proportional guidance coverage from 1.8 degree down to the required system coverage minimum angle of 1 degree. The ± 10 degrees azimuth coverage for the elevation antenna is exceeded as shown (see also Figure 2-4).

Figure 5-22 shows that the 15-nmi range requirement is easily satisfied, and altitude coverage to 10,000 feet is illustrated. The azimuth coverage requirement is satisfied at 20 nmi.

5.3.3.2 Accuracy

5.3.3.2.1 Accuracy Requirements - Table 2-7 shows the 2-sigma requirements for the path following error at the error window and how the error bounds are degraded away from the error window. The minimum guidance altitude above threshold for Category I performance is 150 feet. The elevation error window for a 2.5-degree glide slope is located 7,436 feet from the AZ antenna and at a height of 150 feet above threshold. The glide slope passes through the elevation antenna phase center displaced to runway centerline. The mean of the error data taken over 10-second intervals must be within the 2-sigma path following error bounds.

Table 2-8 presents the 2-sigma requirements on control motion noise and how these error bounds are degraded linearly for distances greater than the error window. Ninety-five percent of the error data taken over a 10-second interval must be within the control motion noise bounds. Another way to say this is that twice the standard deviation of the error data must not exceed the control motion noise error bounds.

5.3.3.2.2 Error Data - Figures 5-23 and 5-24 show the Small Community azimuth and elevation path following error performance for centerline flight tests on a 3-degree glide slope. Also shown are the Category I 2-sigma path following error bound limits specified for MLS Phase III tests. The azimuth angular error bounds are larger than the limits shown in Table 2-7 because the test runway was 5000 feet, while the Table 2-7 error is specified at 10,000 feet. The significant factor is that the 2-sigma lateral path following error does not exceed the specified 58-foot error when the aircraft altitude is 150 feet. The path following error requirement is clearly satisfied since all of the points are within the path following error bounds.

The control motion noise requirements are that the 2-sigma value of the errors be less than 0.1 degree, or equivalent, and that 95 percent of the points measured in a 10-second interval must be within error bounds separated by 0.2 degree. The control motion noise requirement is clearly satisfied as shown by Figures 5-25 and 5-26.

BSC NAFEC RHY 8 DATE : 04/15/77 START TIME 13:38
 AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
 THEOD SS ACFT: DC-6 RUN: 3 DEO APPR AC ANT 300 DEO PFE FILTER OUTPUT

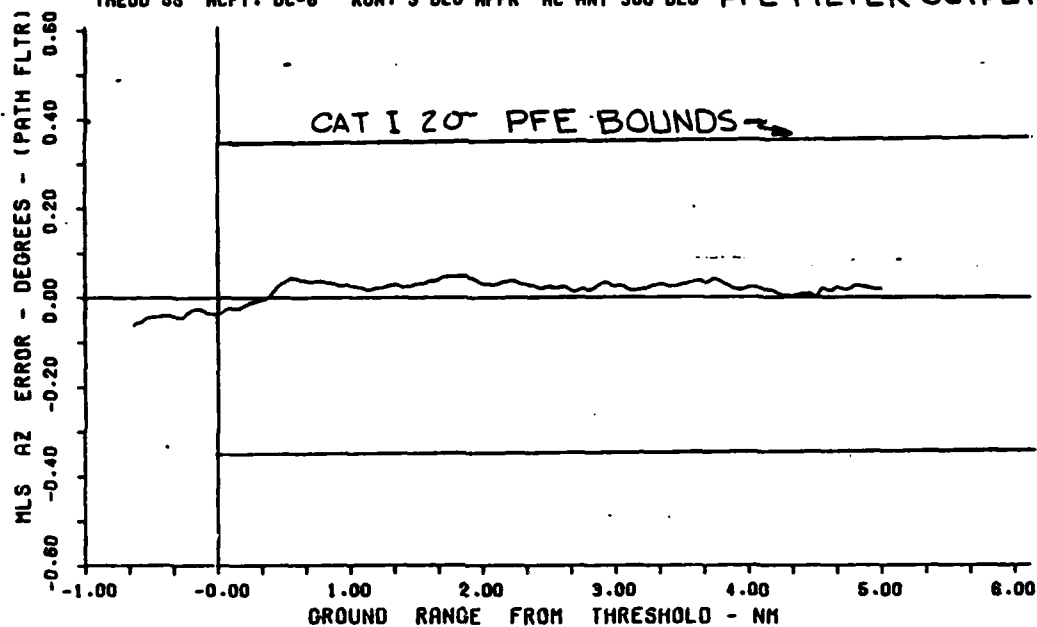


FIGURE 5-23. SMALL COMMUNITY AZ, PFE FOR 3° GLIDESLOPE

BSC NAFEC RHY 8 DATE : 04/15/77 START TIME 13:38
 AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
 THEOD SS ACFT: DC-6 RUN: 3 DEO APPR AC ANT 300 DEO PFE FILTER OUTPUT

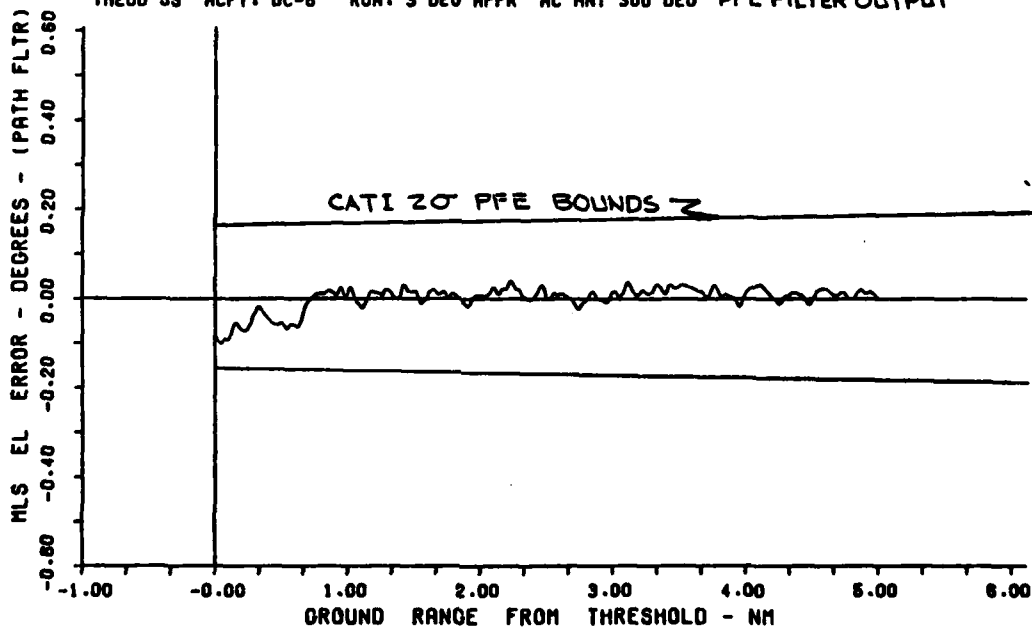


FIGURE 5-24. SMALL COMMUNITY EL ANTENNA, PFE FOR 3° GLIDESLOPE

BSC NAFEC RMY 8 DATE : 04/16/77 START TIME 13:38
 AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
 THEOD SS ACFT: DC-8 RUN: 3 DEO APPR AC ANT 300 DEO CMN FILTER OUTPUT

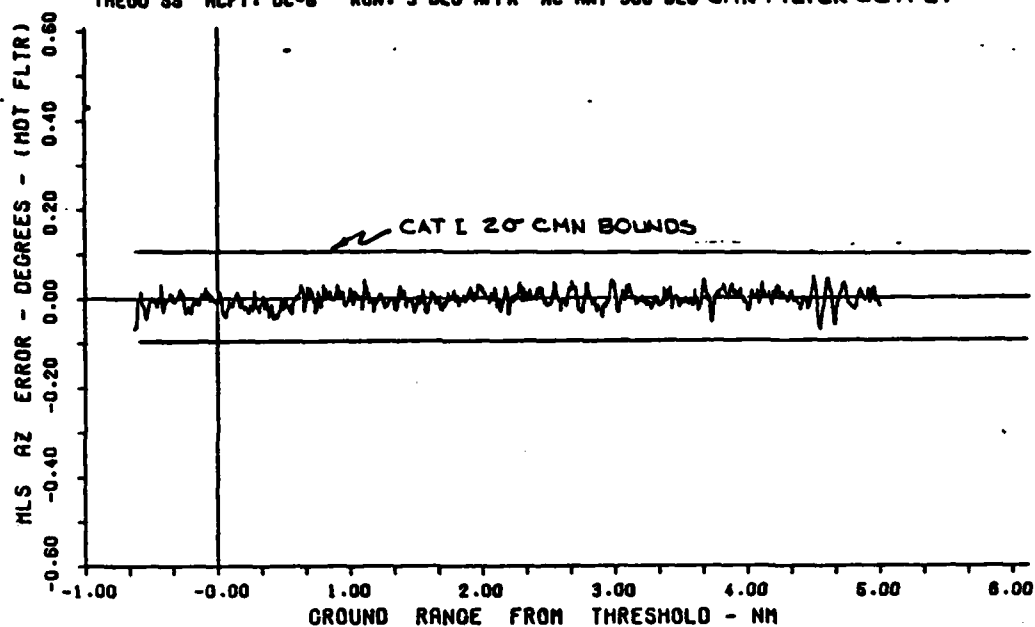


FIGURE 5-25. SMALL COMMUNITY AZ ANTENNA, CMN FOR 3° GLIDESLOPE

BSC NAFEC RMY 8 DATE : 04/16/77 START TIME 13:38
 AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
 THEOD SS ACFT: DC-8 RUN: 3 DEO APPR AC ANT 300 DEO CMN FILTER OUTPUT

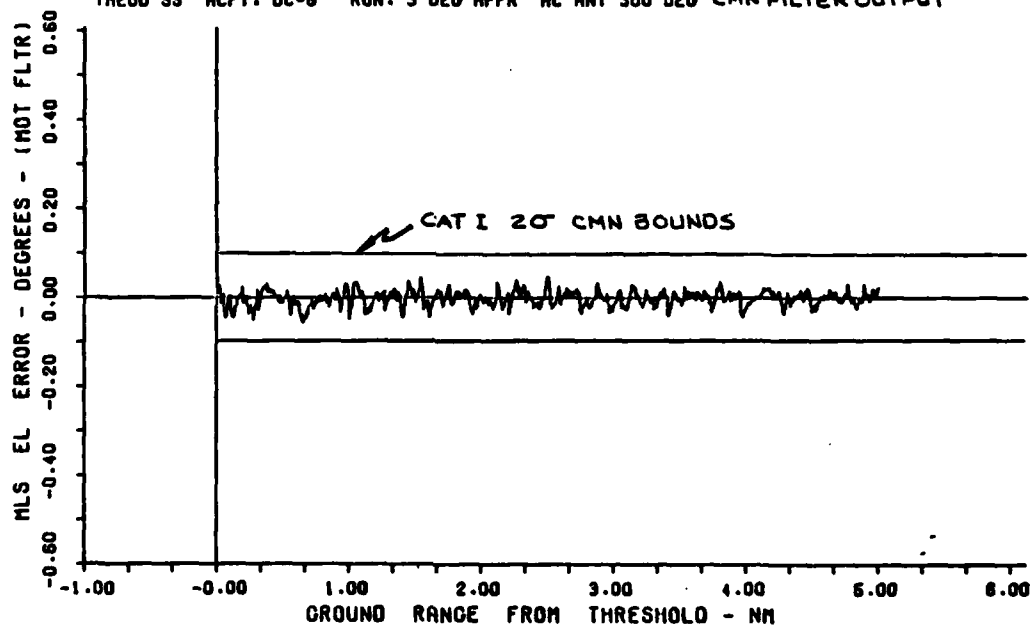


FIGURE 5-26. SMALL COMMUNITY EL ANTENNA, CMN FOR 3° GLIDESLOPE

5.3.3.2.3 Statistical Error Data - Table 5-14 shows the cumulative mean and 2-sigma errors for single runs of selected flight data. The coverage over which the errors were obtained is also shown. The cumulative errors are the averages of all the mean and 2-sigma errors for each 10 second data interval over the entire run.

The mean error over 10 seconds of flight must be less than the 2-sigma path following error (PFE) bounds. Two-sigma PFE bounds are usually smallest at the error window. For the NAFEC Small Community ground system, the autoland specification at the error window for a 3-degree glide slope is +0.155 degree. It is seen that the mean error over the coverage interval of each run in Table 5-14 is significantly less than the 3-degree glide slope error window bound.

The 2-sigma control motion noise (CMN) over 10-second flight intervals must be less than the 2-sigma CMN specification. The worst-case autoland CMN specification (Table 5-15) is 0.10 degree in azimuth and 0.05 degree in elevation. Table 5-14 shows that the average 2-sigma CMN over each run is less than 0.05 degree, except for the 2000-foot overflight and the 20 nmi 10,000-foot altitude orbit. The average 2-sigma CMN for the 2000-foot overflight exceeds the worst-case autoland CMN specification by only 0.007 degree.

5.3.3.3 Autoland Performance Capability - Since a design goal was Category III (autoland performance), it is informative to compare the data with this goal. To show accuracy performance for automatic landings, it is important to evaluate static test data as well as flight data.

5.3.3.3.1 Autoland Accuracy Requirements - Table 5-16 shows the azimuth 2-sigma path following error (PFE) bounds of 0.16 degree at the error window. Inside the error window, the requirement for Category III performance is a 13.5-foot lateral PFE and a 1.8-foot vertical PFE limit.

Table 5-15 gives the 2-sigma error bounds on control motion noise and how these error bounds are degraded linearly for distances greater than the error window.

5.3.3.3.2 Static Data - Figure 5-27 is an azimuth static test with the test van located near threshold of runway 8/26. Also shown is the 2-sigma path following error bound. Figure 5-27 shows that the mean of the azimuth errors is within the autoland error bound down to a pole height of 5 feet, thus demonstrating airborne antenna autoland performance to a height of 5 feet above runway surface at threshold. The control motion noise specification at threshold is 0.1 degree. Hence, the separation of the 2.5 and 97.5 percentile stars can be as large as 0.20 degree. Figure 5-27 shows that the control motion noise goal is easily satisfied since the greatest separation of the 2-sigma points is 0.1 degree.

TABLE 5-14. SMALL COMMUNITY STATISTICAL DATA (PFE FILTER OUTPUT)

FLIGHT	SUB-SYSTEM	COVERAGE (a)	CUMULATIVE MEAN ERROR (b)	CUMULATIVE 2σ ERROR (b)
3° Centerline Approach	AZ	7 nmi to 0.1 nmi	0.021°	0.035°
	EL	7 nmi to 0.1 nmi	0.012°	0.037°
6° Centerline Approach	AZ	6 nmi to 0.1 nmi	0.023°	0.029°
	EL	6 nmi to 0.1 nmi	0.011°	0.023°
2000 Foot Centerline Overflight	AZ	8 nmi to 0 nmi	0.025°	0.048°
	EL	7 nmi to 0.4 nmi	-0.026°	0.057°
5 nmi Orbit at 2000 Foot Altitude	AZ	-10° to 11°	0.011°	0.089°
	EL	-10° to 15°	0.003°	0.037°
20 nmi Orbit at 10,000 Foot Altitude	AZ	-11° to 12°	0.070°	0.055°
	EL	-14° to 15°	0.050°	0.040°

(a) Ground range from threshold or azimuth angle.

(b) Average of mean and 2-sigma errors for all 10 second data intervals over entire run.

TABLE 5-15. CONTROL MOTION NOISE SPECIFICATION AT ERROR WINDOW,
TYPE 3 EQUIPMENT

ANTENNA SIGNAL	CMN (2 σ)	CMN ALLOWABLE DEGRADATION (b)		
		W/DISTANCE (a)	WITH AZ ANGLE	WITH EL ANGLE
AZIMUTH	0.10°	1.4:1 at 20 nmi	None	None
ELEVATION	0.05°	1.4:1 at 20 nmi	None	None

NOTES:

- (a) Distance is slant range from the elevation antenna phase center.
(b) Degradation varies linearly between the limits indicated.

TABLE 5-16. PATH FOLLOWING ERROR SPECIFICATION AT ERROR WINDOW,
TYPE 3 EQUIPMENT

ANTENNA SIGNAL	PFE (2 σ)		DISTANCE TO ERROR WINDOW (FT.) (b)	PFE ALLOWABLE DEGRADATION (a)		
	FT.	DEGREE		W/DISTANCE (b)	WITH AZ ANGLE	WITH EL ANGLE
AZIMUTH	13.5	0.16	5000	Linearly to 0.16° at 20 nmi	2:1 in Angle from Center- line Error at +60° AZ	2:1 in Angle from 9° to 20° Elevation
ELEVATION	1.8	0.13	5010	1.5:1 in Angle at 20 nmi	None	3:1 in Angle from 2° to 20°

NOTES:

- (a) Degradations vary linearly between the limits indicated.
(b) Distance in slant range from the azimuth antenna phase center.
(c) Distance from EL antenna

U.S. PHASE 3 TEST---BENDIX SC STATIC TEST, AZ ANTENNA

- MEAN AND S/D
* 2.5 AND 97.5 PERCENTILES

TEST NO.: 1
DATE: 27/ 4/ 77
TIME: 025

SURVEY PT. = 727 X= 5908.3999 Y= 0.01 Z=-7.37

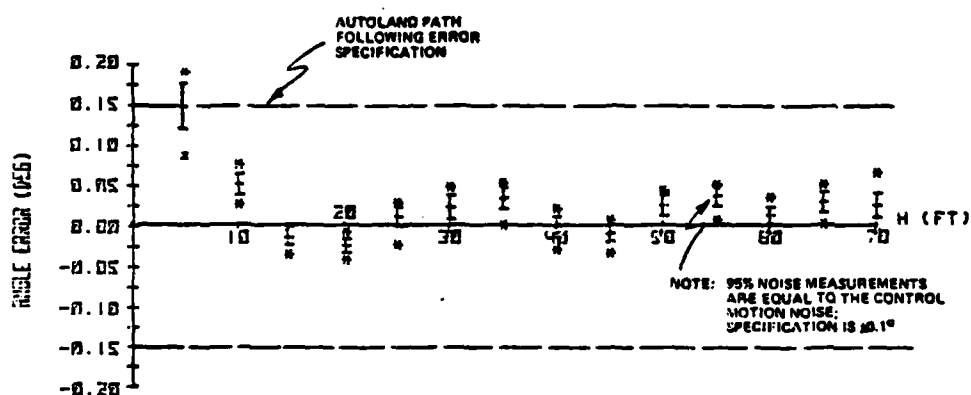


FIGURE 5-27. SMALL COMMUNITY AZ ANTENNA, STATIC TEST
THRESHOLD RUNWAY CENTERLINE

Figure 5-28 represents a static test of the elevation errors 500 feet from threshold on runway 8/26. The autoland path following error specification is satisfied if the mean of the errors at each pole height down to 28 feet is inside the 2-sigma path following error limits. Figure 5-28 shows that the path following requirement for autoland is satisfied. The control motion noise specification for autoland is 0.05 degree. This means that the 1-sigma bar separations in Figure 5-28 must not be larger than 0.05 degree. Since the greatest separation of the horizontal data bars is 0.03 degree, the autoland requirement is satisfied.

5.3.2.3.3 Flight Data - Figures 5-29 through 5-32 show that the Small Community system satisfies the autoland requirement for a centerline approach with a 3-degree glide slope from 7 nmi down to threshold. The data is shown at the output of the path following and control motion filters specified in FAA-ER-700-07. Clearly, the 2-sigma specifications on both PFE and CMN are satisfied, since all data points lie within the 2-sigma bounds.

5.3.3.4 Problems - The three most significant problems which occurred during the Small Community test program are discussed. None of these problems caused path following errors greater than the Phase III accuracy specifications.

5.3.3.4.1 Sloping Bias Error - On 5-nmi orbital flights at 2000 feet altitude, a sloping bias of 0.05 degree per 10 degree change of azimuth occurred in SC EL data as illustrated by Figure 5-33. This problem was identified as a distorted antenna ground plane. Correction of the antenna aperture has resulted in considerable improvement in the test data as illustrated by Figure 5-34.

5.3.3.4.2 Monitor Horn Interference - Illumination of the monitor pole and horn by the scanning beam causes distortion of the scanning beam and errors near centerline. The oscillatory error marked in Figure 5-33 is due to monitor pole and horn interference. The approach being taken to solve this problem is described in paragraph 9.2.3.

5.3.3.4.3 System Turn-Off Due to Rain - During periods of very heavy rainfall, it was observed that rain on the radomes attenuated the effective radiated power (ERP) by an amount which nears the 3 dB degradation of power limit allowed by the monitor. This attenuation, added to component aging, could produce an unacceptable frequency of system shutdown during heavy rains. Table 5-17 shows the results of a test conducted before and during a heavy rain. The data shown in Table 5-17 was taken on the Basic Narrow Azimuth MLS, but is applicable to the SC antenna also. The approaches being taken to solve this problem are discussed in paragraph 9.2.2.

S.C. EL IS STANDARD CONFIGURATION, PLUMB IN BOTH PLANES. OFF SET IS IN POS. 0 9.
 DISTANCE FROM THE EL PHASE CENTER IS 1819.248 FEET. AN ANGLE OF -10.2 DEGS.

BENDIX/NAFEC TRSB MLS STATIC TEST SMALL COMM. ELEVATION PHASE III

S.P. = 734 X= 5202.0 Y= 0.01 Z=-3.83

MLS VAN 0 102
 DATE 11/ 19/ 76
 TIME 0: 39
 TEMP 34 DEG F
 CHANNEL 0 197
 RECEIVER 0 103

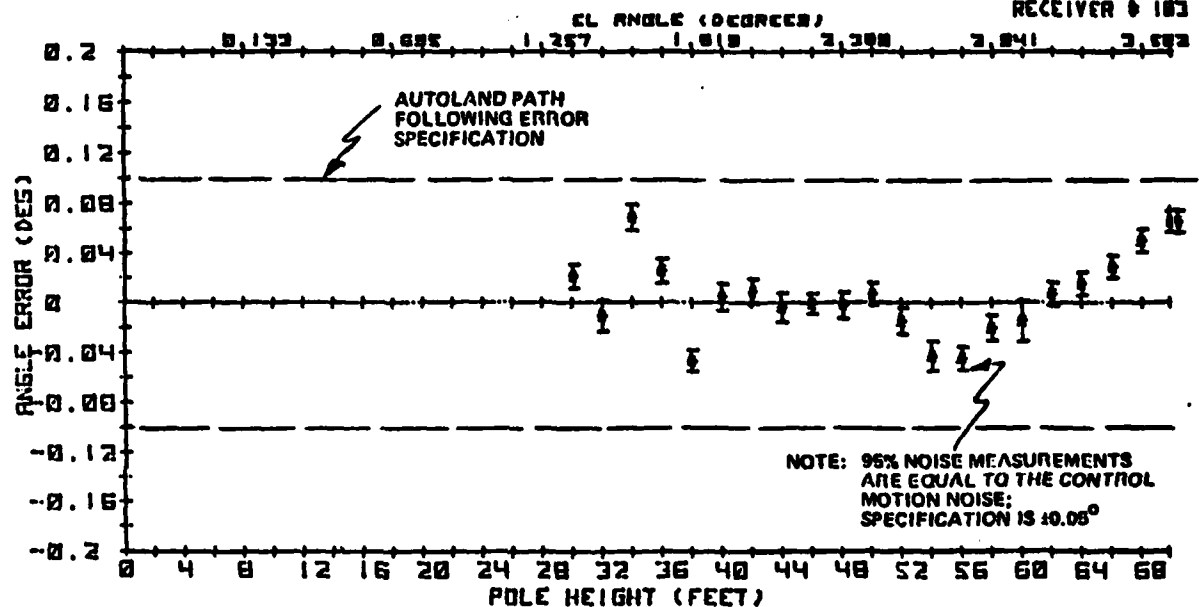


FIGURE 5-28. SMALL COMMUNITY EL ANTENNA, STATIC TEST
 RUNWAY CENTERLINE

BSC NAFEC RMY 8 DATE : 04/15/77 START TIME 13:38
 AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
 THEOD SS ACFT: DC-6 RUN: 3 DEO APPR AC ANT 300 DEO PFE FILTER OUTPUT

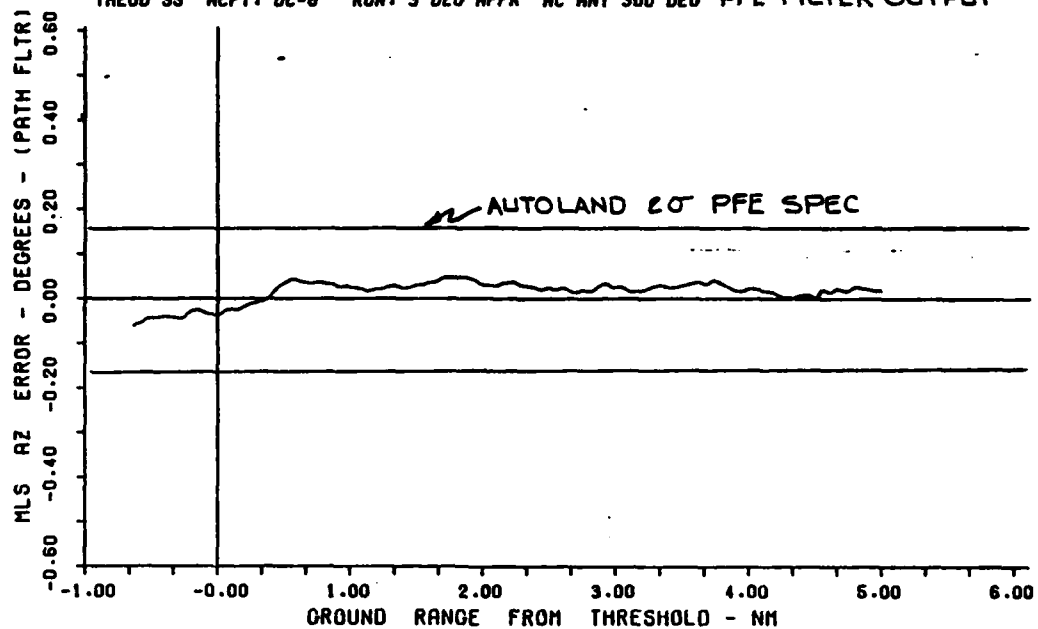


FIGURE 5-29. SMALL COMMUNITY AZ ANTENNA, PFE FOR 3° GLIDESLOPE

BSC NAFEC RMY 8 DATE : 04/15/77 START TIME 13:38
 AZ -5703/00/+6 FT EL -1502/-182/+8 FT DME NA
 THEOD SS ACFT: DC-6 RUN: 3 DEO APPR AC ANT 300 DEO PFE FILTER OUTPUT

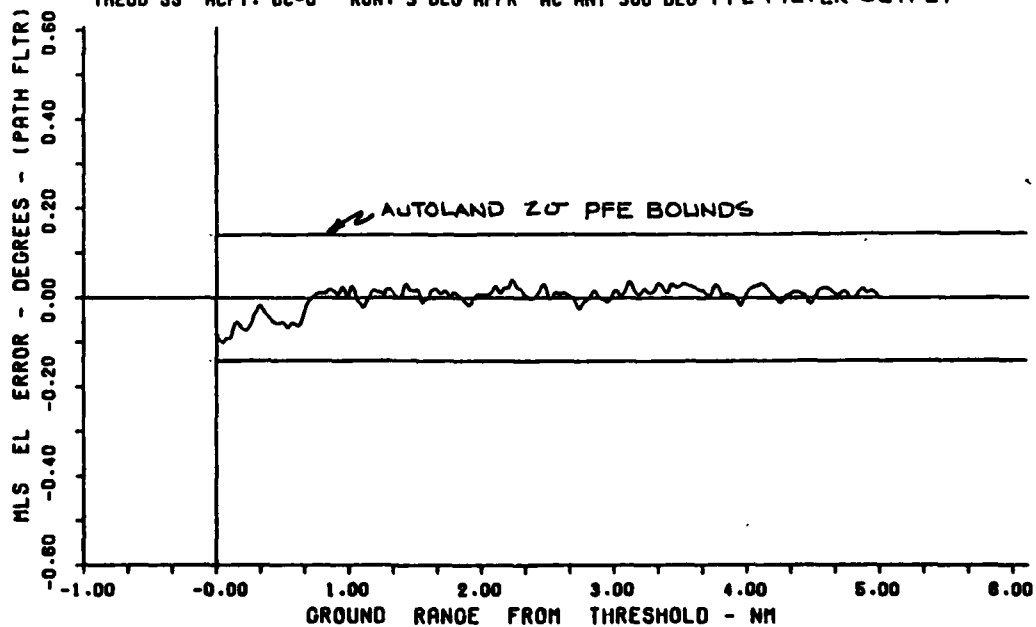


FIGURE 5-30. SMALL COMMUNITY EL ANTENNA, PFE FOR 3° GLIDESLOPE

BSC NAFEC RMY 8 DATE : 04/15/77 START TIME 13:38
 AZ -5703/00/+8 FT EL -1502/-182/+8 FT ONE NA
 THEOD SS ACFT: DC-8 RUN: 3 DEO APPR AC ANT 300 DEO CMN FILTER OUTPUT

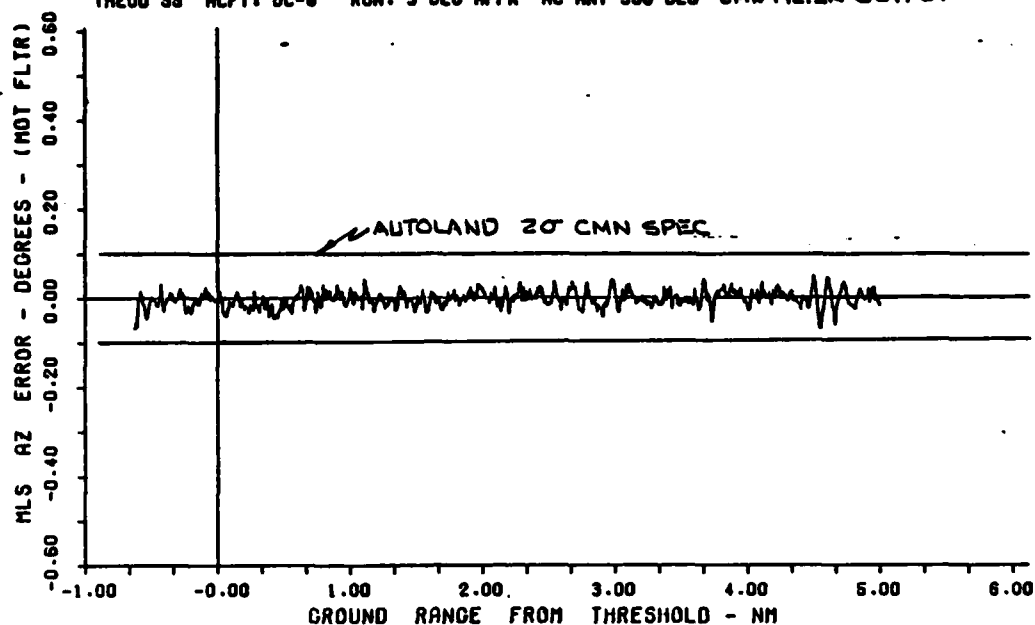


FIGURE 5-31. SMALL COMMUNITY AZ ANTENNA, CMN FOR 3° GLIDESLOPE

BSC NAFEC RMY 8 DATE : 04/15/77 START TIME 13:38
 AZ -5703/00/+8 FT EL -1502/-182/+8 FT ONE NA
 THEOD SS ACFT: DC-8 RUN: 3 DEO APPR AC ANT 300 DEO CMN FILTER OUTPUT

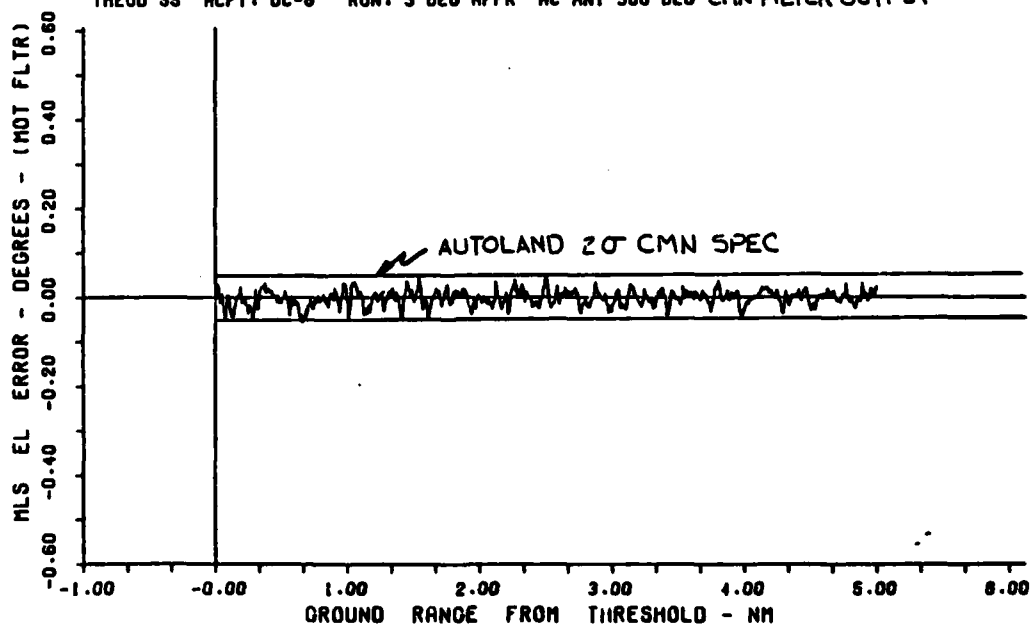


FIGURE 5-32. SMALL COMMUNITY EL ANTENNA, CMN FOR 3° GLIDESLOPE

SC FLIGHT #3 RUN #1 SYSTEM 1

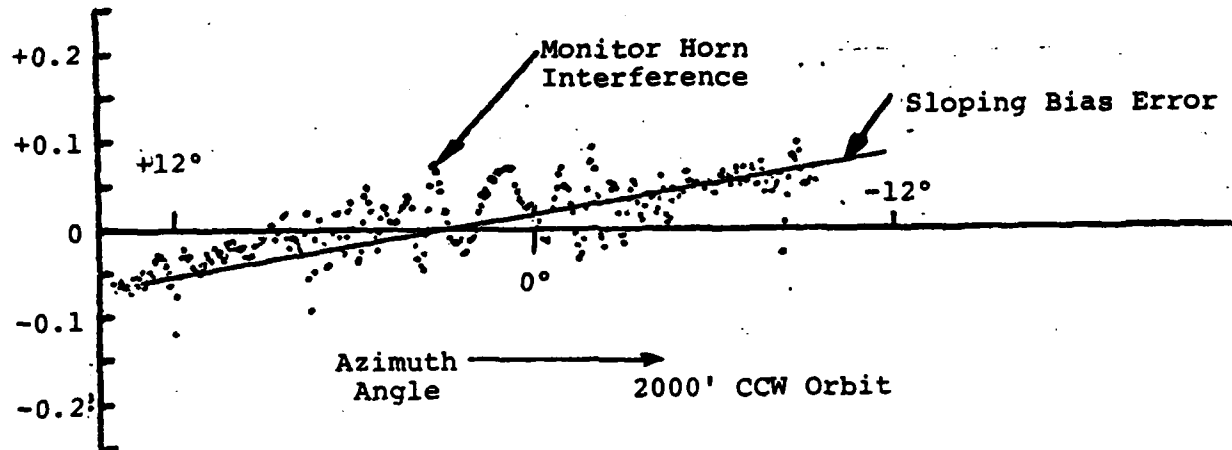


FIGURE 5-33. SMALL COMMUNITY EL ANTENNA, PFE WITH DISTORTED APERTURE

BSC NAFEC RMY 8 DATE : 08/26/77 START TIME 14:07
AZ -5703/00/+8 FT EL -1502/-182/+8 FT ONE NA
THEOD SS ACFT: DC-6 RUN: ORBIT 2K FT AT 5 NM AC ANT OMNI

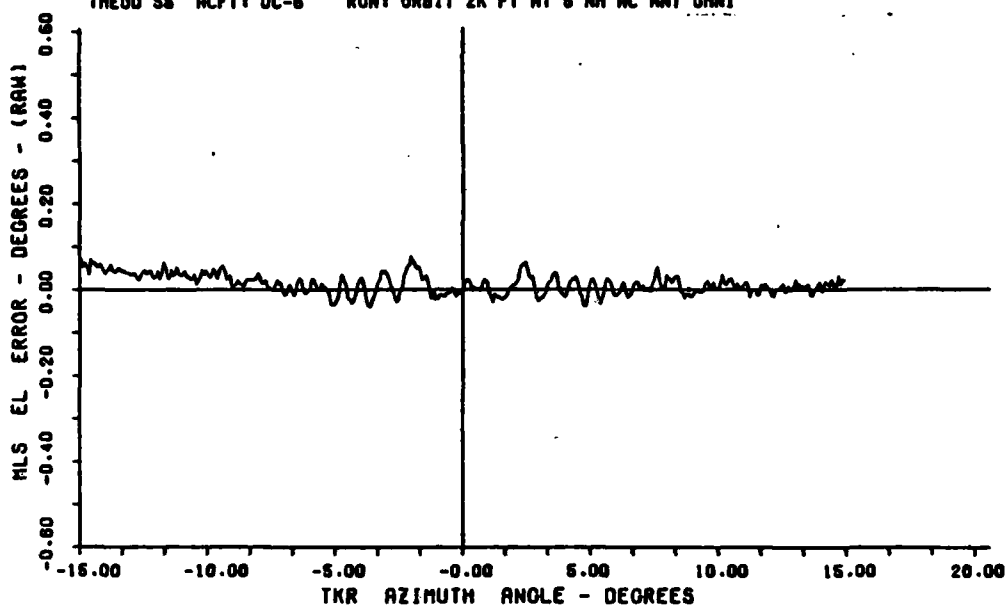


FIGURE 5-34. SMALL COMMUNITY EL ANTENNA, PFE AFTER
CORRECTING DISTORTED APERTURE

TABLE 5-17. MONITORED EFFECTIVE RADIATED POWER
ATTENUATION DUE TO HEAVY RAIN

TIME	EFFECTIVE RADIATED POWER ATTENUATION MEASURED
No Rain	0 dB
Rain Start	-1.2 dB
Progressive Increase In Rain Rate	-1.1 dB
	-1.5 dB
	-1.7 dB
	-2.0 dB
	-2.1 dB
	-2.2 dB
	-2.4 dB
Heavy Rain	-2.7 dB

5.3.3.5 Summary of Small Community Field Test Results - It has been shown that horizontal and vertical proportional guidance coverage requirements for aircraft flying at 10,000 feet and 2,000 feet have been satisfied. The accuracy performance not only exceeds the Phase III Category I requirements, but also fully satisfies autoland requirements specified for Category III systems. Systematic errors effecting the accuracy of the system have occurred and three of the most significant problems and associated corrective procedures have been discussed.

5.4 DEMONSTRATION TESTS

During the period from September 1977 to March 1978, the Basic Narrow and Small Community systems were demonstrated and tested at eight operational airports in North America, Central America, South America, Europe, and Africa. Each of these demonstrations is summarized in Tables 5-18 through 5-25. The data in these tables was obtained from the referenced FAA reports.

TABLE 5-18. DEMONSTRATION SUMMARY

AIRPORT	Cape May, New Jersey, USA
DATE	27 September 1977 to 8 October 1977
SYSTEM	Small Community
RUNWAY	10/28 (5000 ft)
AIRCRAFT	DC-6, DHC-6 (Twin Otter)
FLIGHTS	3° and 6° Approaches
SITE FEATURES	Split-site configuration; 4-story terminal building and hangar located about 2500 ft at -15° bearing from AZ site; flat terrain.
SUMMARY	<ul style="list-style-type: none"> a) No multipath effects observed. b) Guidance signal quality within ICAO require- ments for reduced capability system. c) Guidance signal quality meets FAA CAT II requirements. d) No prop modulation effects observed.
REFERENCE	FAA-RD-78-13

TABLE 5-19. DEMONSTRATION SUMMARY

AIRPORT	Jorge Newbery Aeroparque, Buenos Aires, Argentina
DATE	17 October 1977 to 4 November 1977
SYSTEM	Basic Narrow
RUNWAY	13/31 (6900 ft)
AIRCRAFT	T-39, Boeing 737, Guarani (twin turbo prop)
FLIGHTS	Segmented and curved approaches with autoland and rollout
SITE FEATURES	Split-site configuration; AZ situated 75 ft in front of ILS localizer; EL situated 30 ft outboard of ILS glide slope antenna; flat terrain
SUMMARY	<ul style="list-style-type: none"> a) ILS performance not affected by collocation with MLS. b) Guidance signal quality within ICAO requirements for full capability system. c) Guidance signal quality meets FAA autoland requirements. d) No prop modulation effects observed.
REFERENCE	FAA-RD-78-14

TABLE 5-20. DEMONSTRATION SUMMARY

AIRPORT	Toncontin International Airport, Tegucigalpa, Honduras
DATE	13 November 1977 to 26 November 1977
SYSTEM	Small Community
RUNWAY	01/19 (5900 ft)
AIRCRAFT	CV-580 (twin turbo-prop)
FLIGHTS	0°, 3°, 9° radial approaches with glide slopes of 3.5° to 4.5°
SITE FEATURES	Collocated configuration; mountainous topology in surrounding countryside.
SUMMARY	<ul style="list-style-type: none"> a) Demonstrated offset approach angle capability b) Guidance signal quality within ICAO requirements for reduced capability system.
REFERENCE	FAA-RD-78-15

TABLE 5-21. DEMONSTRATION SUMMARY

AIRPORT	Kjevik Airport, Kristiansand, Norway
DATE	15 January 1978 to 27 January 1978
SYSTEM	Basic Narrow, Small Community
RUNWAY	22 (6234 ft)
AIRCRAFT	Boeing 727
FLIGHTS	0°, ±1°, -20°, and -3° radials 10 and 20 NMi orbital 2.5°, 3°, and 3.5° approaches (centerline, ±1°, -2°)
SITE FEATURES	Split-site configurations Approach is along valley AZ offset from centerline
SUMMARY	a) Guidance signal quality of both systems within ICAO requirements for full capa- bility system. b) Demonstrated capability under difficult weather and terrain conditions
REFERENCE	FAA-RD-78-17

TABLE 5-22. DEMONSTRATION SUMMARY

AIRPORT	Gosselies Airport, Charleroi, Belgium
DATE	28 January 1978 to 6 February 1978
SYSTEM	Small Community
RUNWAY	25 (8366 ft)
AIRCRAFT	Boeing 727, Convair 880
FLIGHTS	2.5°, 3°, and 4° approaches (centerline, $\pm 1^\circ$, $\pm 2^\circ$) $\pm 10^\circ$ radials Autoland
SITE FEATURES	Split-site configuration AZ 328 ft in front of ILS localizer EL located outboard of ILS glide slope antenna Runway severely humped (about 27 ft)
SUMMARY	a) Guidance signal quality within ICAO requirements for full capability system b) No mutual interference with ILS observed c) Severe runway geometry did not effect accuracy
REFERENCE	FAA-RD-78-19

TABLE 5-23. DEMONSTRATION SUMMARY

AIRPORT	Yoff Airport, Dakar, Senegal
DATE	9 February 1978 to 15 February 1978
SYSTEM	Small Community
RUNWAY	01 (11,450 ft)
AIRCRAFT	Boeing 727
FLIGHTS	3°, 3.5°, 4° approaches (centerline, -10° radial) Autoland 10 NMI orbital
SITE FEATURES	Split-site configuration AZ located 60 ft in front of ILS localizer EL located 16 ft inboard of ILS glide slope antenna Flat terrain Runway humped (about 20 ft)
SUMMARY	a) Guidance signal quality within ICAO requirements for full capability system b) No mutual interference with ILS observed
REFERENCE	FAA-RD-78-21

TABLE 5-24. DEMONSTRATION SUMMARY

AIRPORT	Embakasi International Airport, Nairobi, Kenya
DATE	20 February 1978 to 24 February 1978
SYSTEM	Small Community
RUNWAY	06 (13,507 ft)
AIRCRAFT	Boeing 727
FLIGHTS	3°, 3.5°, 4° approaches Autocoupled
SITE FEATURES	Split-site configuration AZ located 1197 ft in front of ILS localizer EL located 66 ft inboard of ILS glide slope antenna
SUMMARY	a) Guidance signal quality within ICAO requirements for full capability system b) Demonstrated collocation with ILS
REFERENCE	FAA-RD-78-22

TABLE 5-25. DEMONSTRATION SUMMARY

AIRPORT	Shiraz International Airport, Shiraz, Iran
DATE	1 March 1978 to 8 March 1978
SYSTEM	Small Community
RUNWAY	29R (14,009 ft)
AIRCRAFT	Boeing 727
FLIGHTS	3°, 3.5°, and 4° centerline approaches 0°, ±5°, ±10° radials 5 Nmi orbital Autocoupled
SITE FEATURES	Split-site configuration Collocated with ILS Flat terrain ALS on runway 29L
SUMMARY	a) Guidance signal quality within ICAO requirements for full capability system b) Demonstrated collocation with ILS c) Demonstrated feasibility of single ground system serving two parallel runways
REFERENCE	FAA-RD-78-23

SECTION 6

SITING CONSIDERATIONS AT NAFEC

6.1 INTRODUCTION

In order to achieve the high performance potential of the MLS, attention must be paid to proper siting with respect to known runway equipments, airport structures, and terrain. Siting will depend upon split or collocated configurations, local topography, obstruction clearance regulations, ILS and ALS collocation requirements, and class of service to be provided.

6.2 BASIC NARROW SYSTEM

Obstruction clearance planes are described by a series of imaginary surfaces as defined in FAR Part 77. Runway 13/31 at NAFEC is a precision instrument, 10,000-foot runway with a hard paved 200-foot extension past the threshold on each end. The clearance plane diagram for this runway is shown in Figure 6-1. The primary surface extends 500 feet either side of the runway centerline and extends past both thresholds 200 feet (1000 x 10,400 feet).

The five surfaces that comprise the obstruction clearance model are the primary surface, the approach surface, the horizontal surface, the conical surface, and the transitional surface.

The BN AZ equipment is located at the end of runway 31, and is under the approach plane surface. The BN EL equipment is located to one side of the runway and is under the primary surface. Figures 6-2 through 6-5 contain siting data for the BN system. Plan and elevation views are shown for both AZ and EL equipments. Figures 6-2 and 6-3 indicate that the BN AZ antenna case and equipment shelter penetrate the clearance plane. This was necessary since there is an ILS monitor horn to the rear of the AZ antenna. To satisfy the ILS/MLS collocation requirement and to not violate the ILS critical area, it is necessary that the MLS be located forward of the ILS localizer and monitor. An exception to the FAR was obtained in this case. The top of the antenna case protrudes 1.64 feet past the clearance plane (2.74 feet including the obstruction light). The antenna is positioned so that adequate clearance over the nearest ALS* station is provided. The monitor horn also protrudes past the clearance plane by 2.29 feet, including the obstruction light. The equipment shelter also penetrates the clearance plane by 2.21 feet (3.31 feet including the obstruction light), but is located 200 feet off the runway centerline extended. There are no problems in meeting rollout requirements since the runway has a positive

*Approach Lighting System

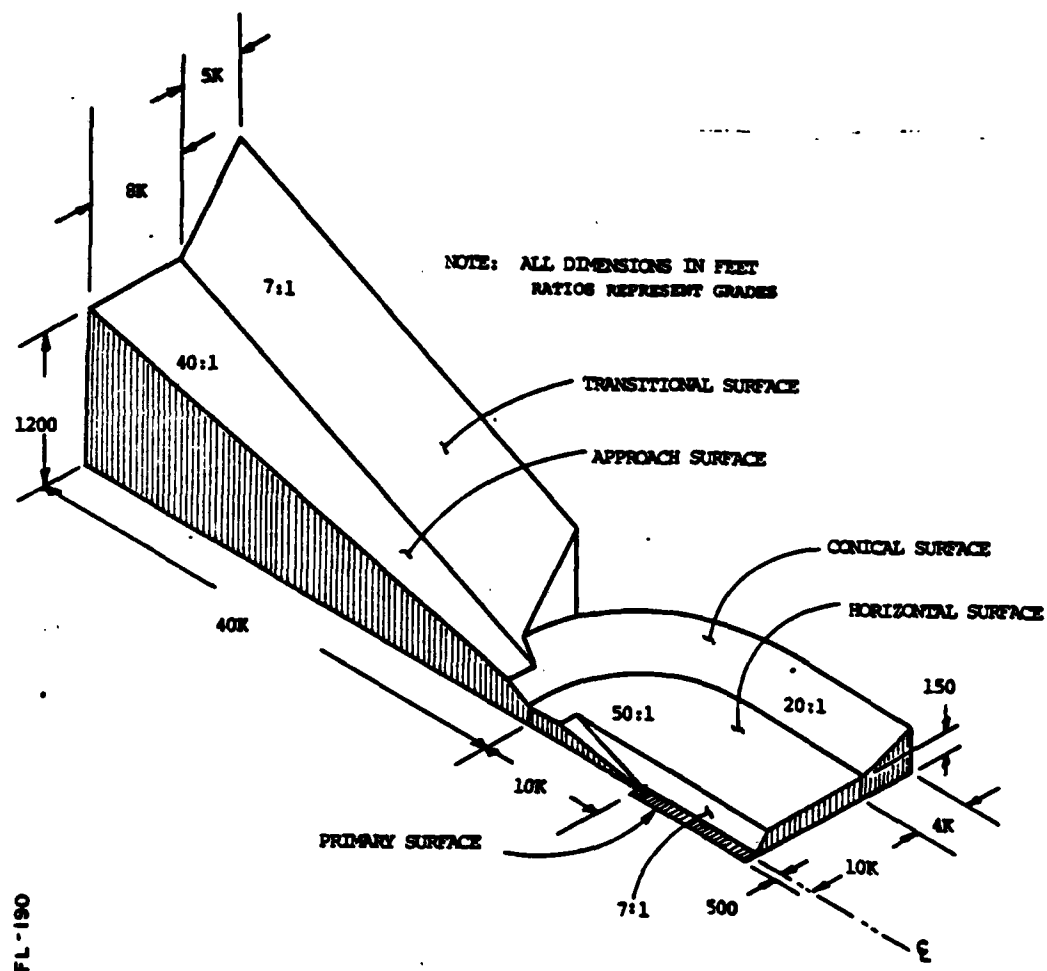
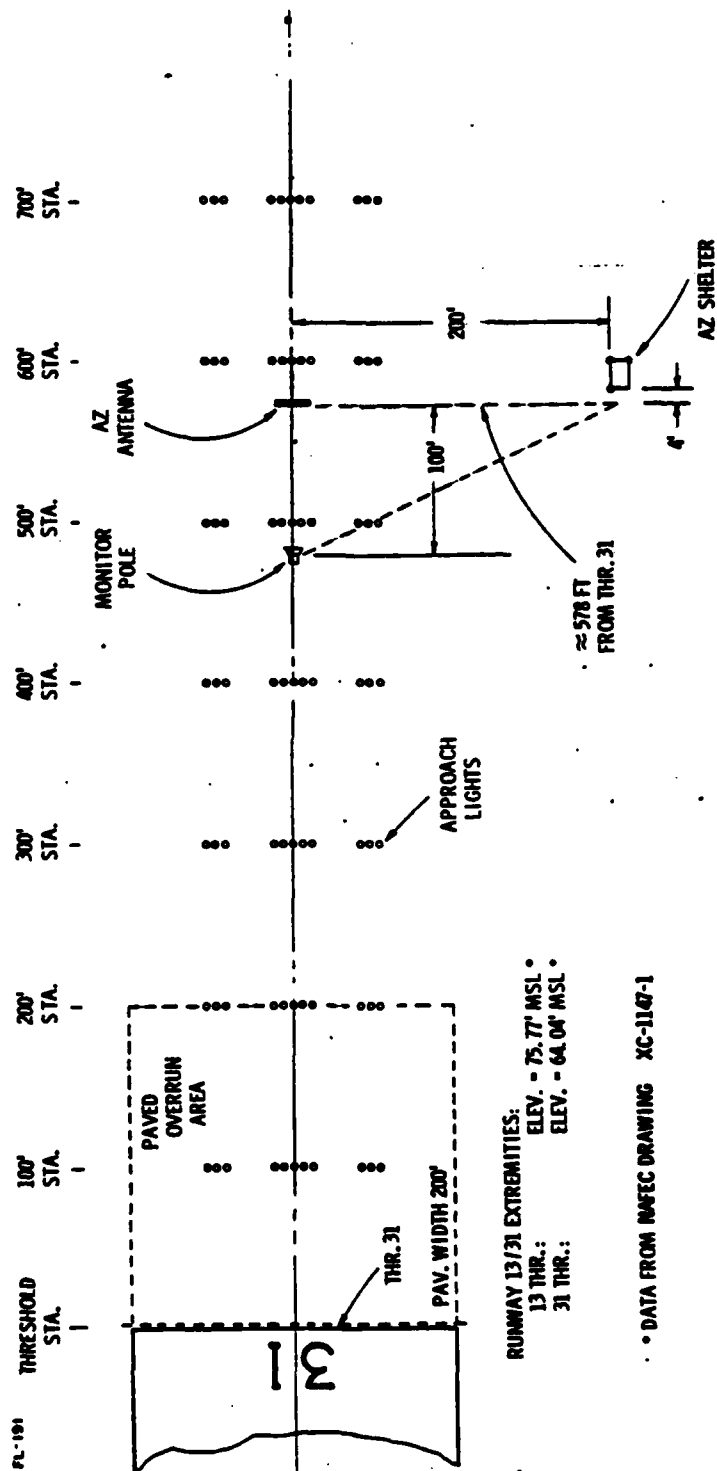


FIGURE 6-1. RUNWAY 13/31 CLEARANCE PLANES



RUNWAY 13/31 EXTREMITIES:
 13 THR.: ELEV. = 75.77' MSL
 31 THR.: ELEV. = 64.04' MSL

• DATA FROM NAEC DRAWING XC-1147-1

FIGURE 6-2. BN AZ SITING (PLAN VIEW), RUNWAY 31

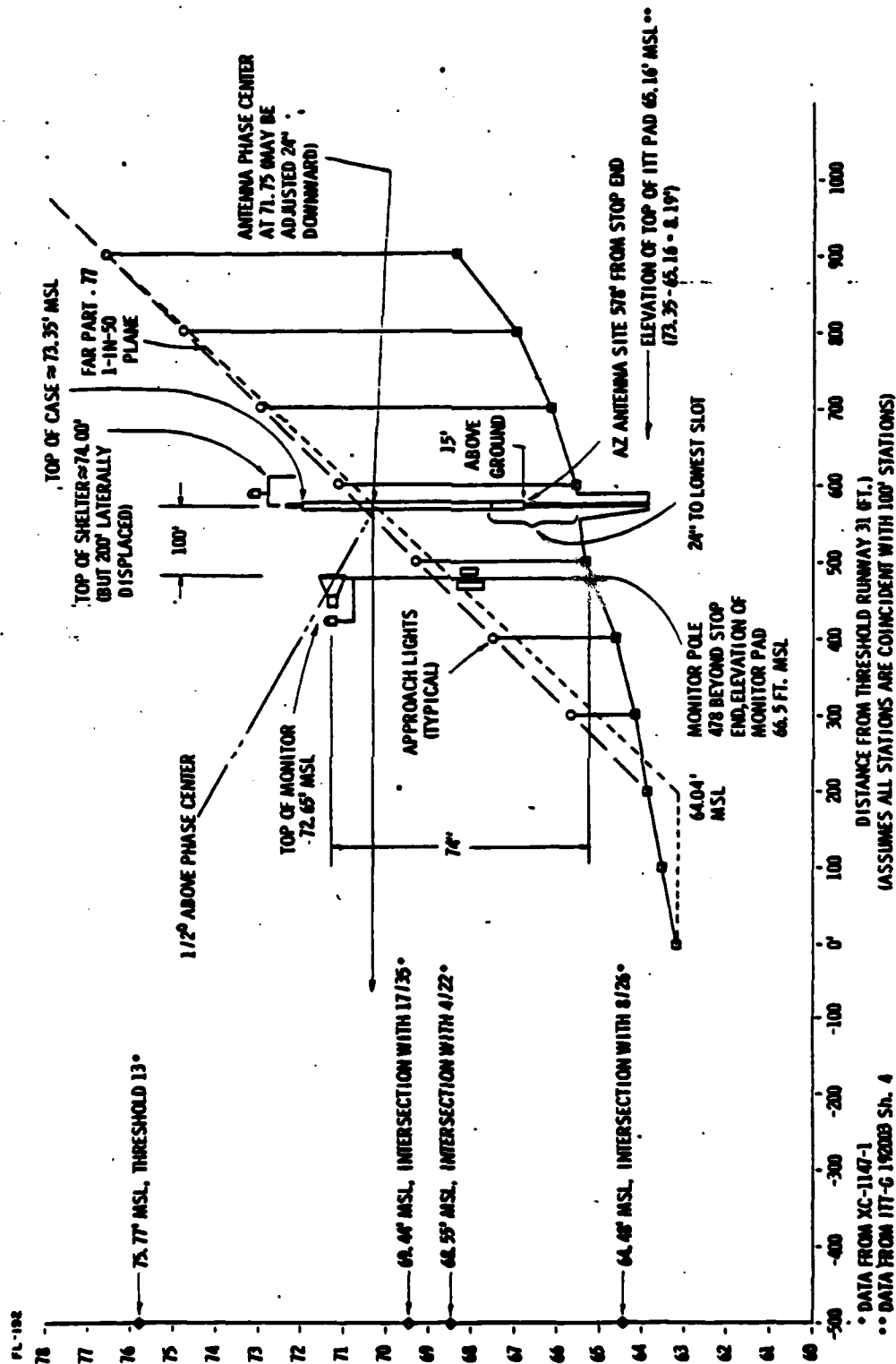


FIGURE 6-3. BN AZ SITING (ELEVATION VIEW), RUNWAY 31

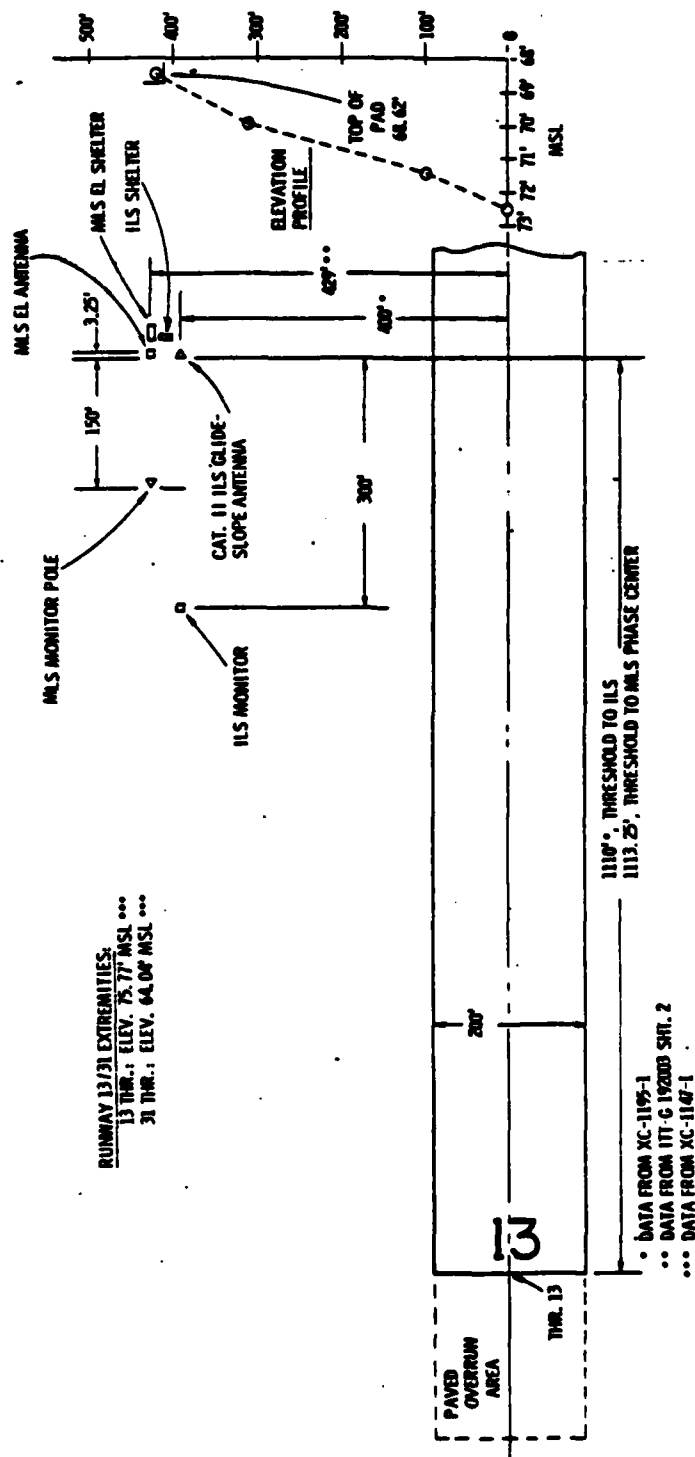


FIGURE 6-4. BN EL. SITING (PLAN VIEW), RUNWAY 13

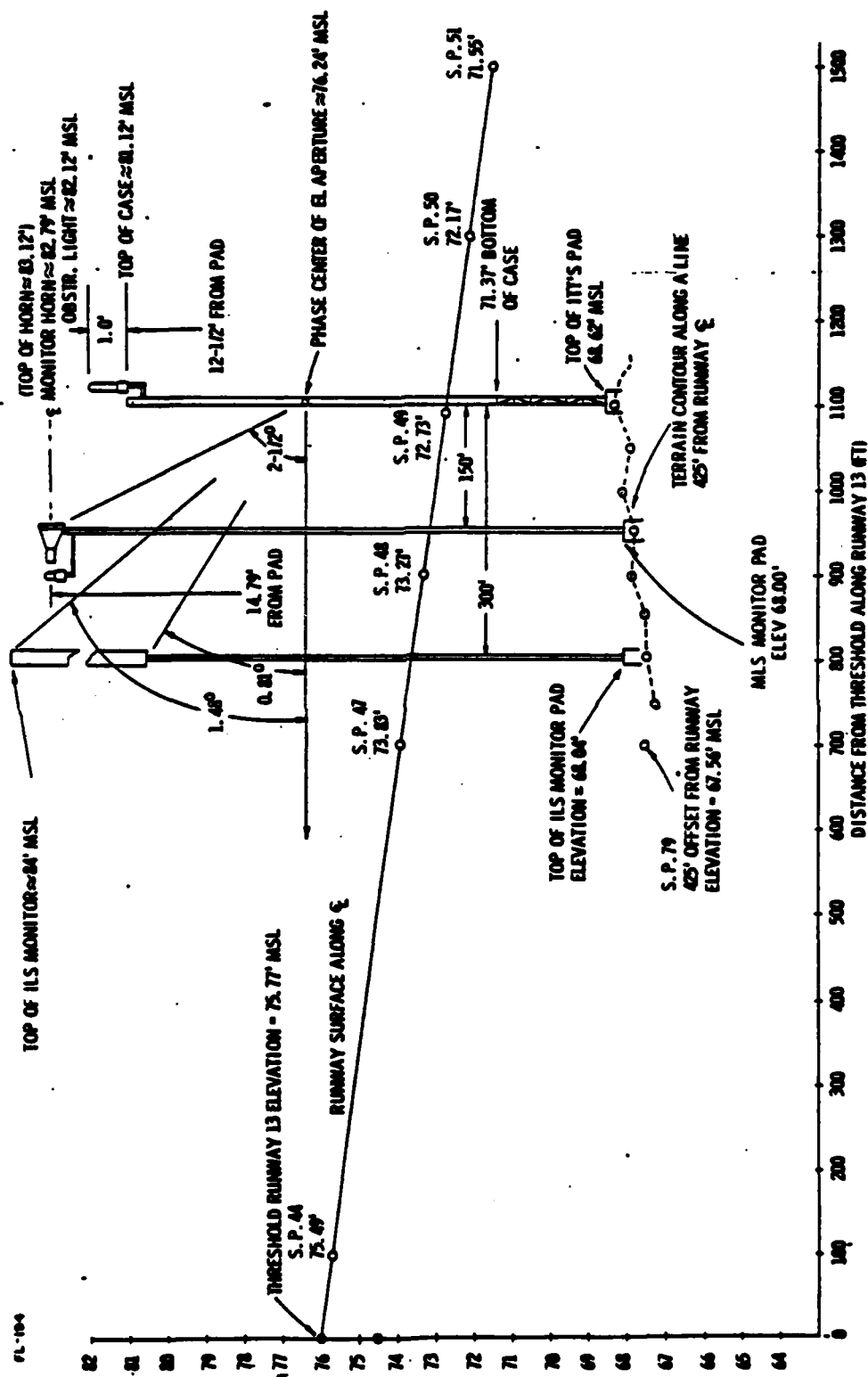


FIGURE 6-5. BN EL SITING (ELEVATION VIEW), RUNWAY 13

grade from threshold 31 to threshold 13 (64.15 MSL to 75.77 MSL), and the AZ signal will not be shadowed.

The BN EL equipment, Figures 6-4 and 6-5, is in a similar situation, being within the primary surface clearance plane. However, since an ILS glide slope antenna is located within 400 feet of runway centerline and the height of MLS is less than the ILS, it was decided to locate the EL antenna near the ILS glide slope antenna. This will keep the GPIIP for ILS and MLS proximate.

To avoid the critical zone for the ILS glide slope antenna, the EL antenna was located outboard of and slightly (3.25 feet) behind the ILS antenna at an existing pad. This position permitted the EL antenna to have line-of-sight contact with threshold 13 by looking between the ILS antenna and monitor. The phase center of the EL antenna is within 0.5 feet of the threshold 13 elevation.

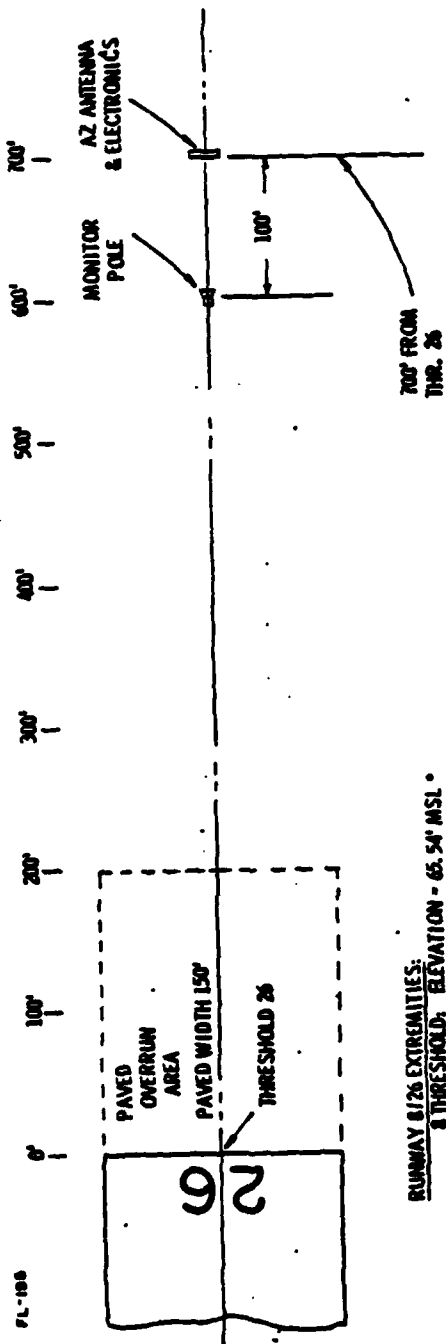
The BN siting at NAFEC represents a case where collocation with both ILS and ALS was achieved. Tests (section 5.0) showed that performance did not degrade for either the ILS or the MLS.

6.3 SMALL COMMUNITY

NAFEC Runway 8/26 is a 5000-foot runway with a 200-foot paved overrun area at each end. As noted in Figure 6-7, the runway is convex with the peak altitude 3 feet above threshold 26 and 1.5 feet above threshold 8.

The AZ subsystem is shown in Figures 6-6 and 6-7. The antenna is located 700 feet from threshold 26, and the maximum heights of the antenna case and monitor horn are within the approach clearance plane. The AZ antenna can be adjusted vertically so that the phase center is 3.25 feet higher than the maximum runway elevation. This permits signals to be received by the aircraft during rollout. There are no ILS or ALS equipments near the AZ site.

Siting of the SC EL equipment is shown in Figures 6-8 and 6-9. This system is within the primary surface of runway 8/26, but due to the proliferation of runways and taxiways in the vicinity of threshold 8, this represented a near optimum solution. The monitor horn and antenna cases are about 13.6 and 11.6 feet above the runway centerline, respectively. There are no terrain problems at this site and no ILS antennas are present. The EL site is located 1500 feet from the threshold and not the typical 1000 feet because of the utilization of an existing foundation.



RUNWAY 8/26 EXTREMITIES:
 8 THRESHOLD; ELEVATION - 65.54' MSL •
 26 THRESHOLD; ELEVATION - 64.07' MSL •

• DATA FROM NAEC DRAWING XC-1147-1

FIGURE 6-6. SC AZ SITING (PLAN VIEW), RUNWAY 26

FL-197

RUNWAY 8/26 EXTREMITIES:
 8 THR.: ELEVATION 65.54' MSL
 26 THR.: ELEVATION 64.07' MSL

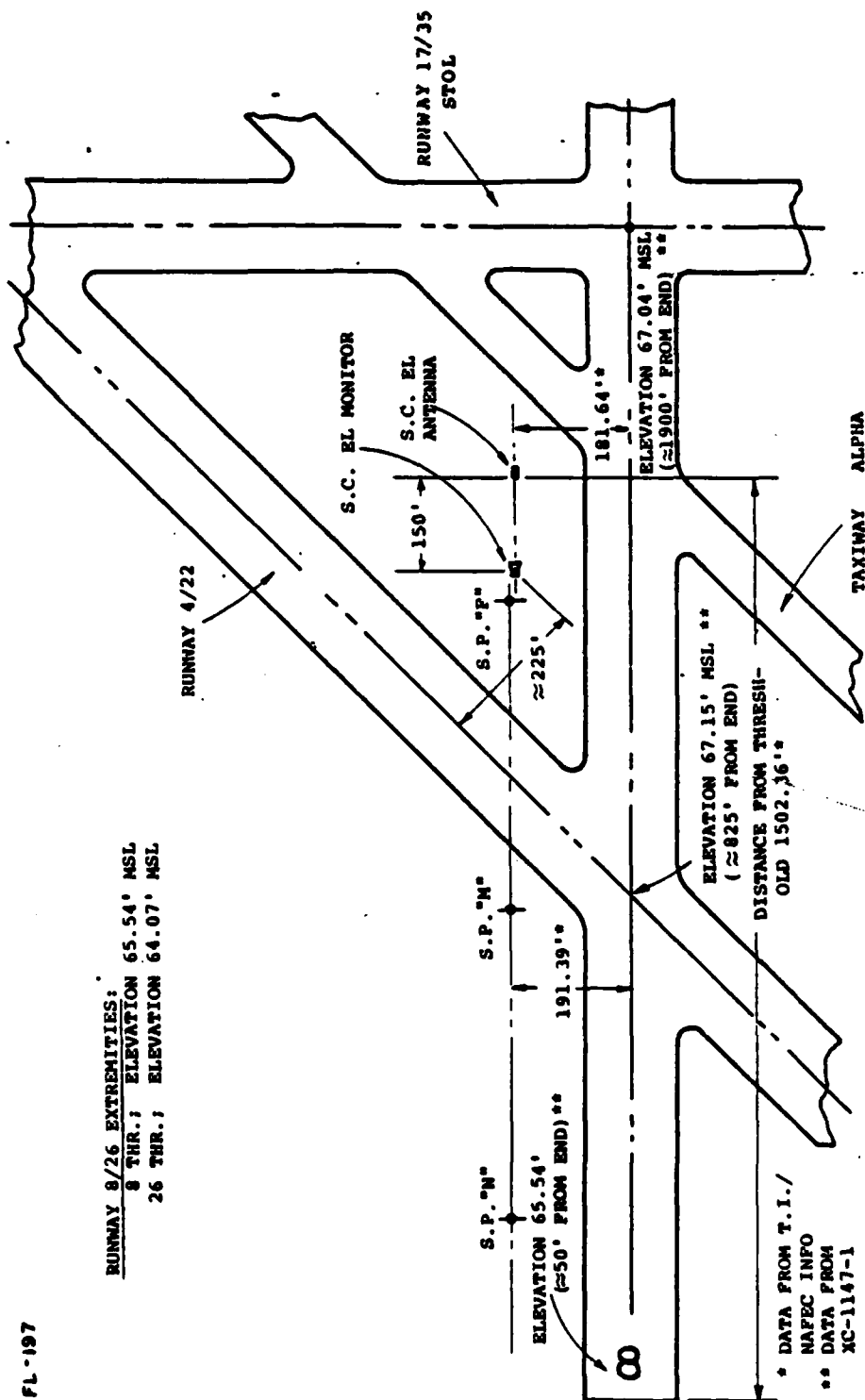


FIGURE 6-8. SC EL SITING (PLAN VIEW), RUNWAY 8

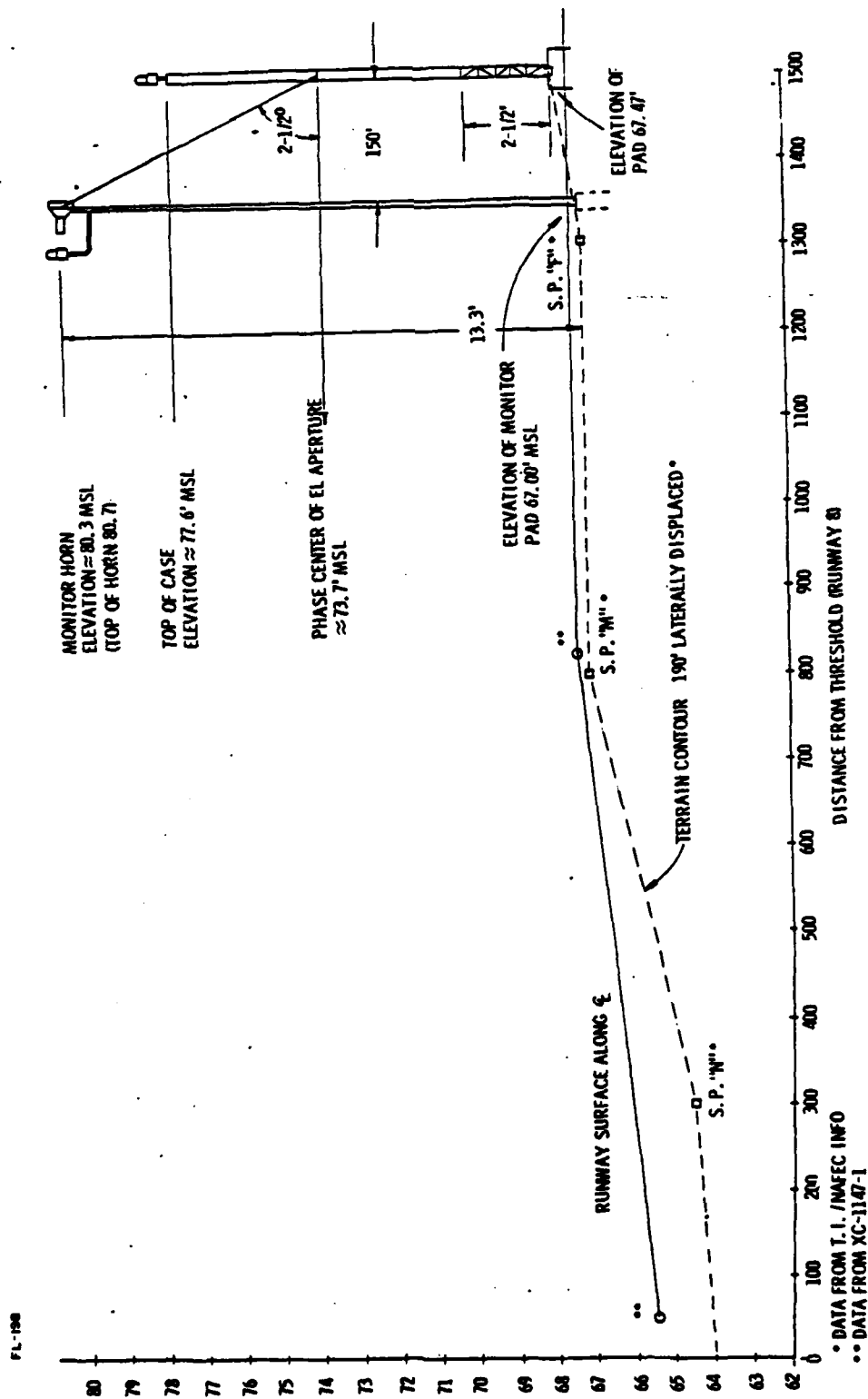


FIGURE 6-9. SC EL SITING (ELEVATION VIEW), RUNWAY 8

SECTION 7

RELIABILITY AND MAINTAINABILITY ANALYSIS

7.1 INTRODUCTION

Detailed reliability and maintainability analyses were performed on the ground and airborne subsystems for the Basic Narrow and Small Community configurations. This section summarizes the results of these analyses, which are described in detail in Appendices B - Reliability Test Plan, C - Reliability Analysis Report (Ground Equipment) D - Maintainability Plan, and E - Reliability Analysis Report (Airborne Equipment).

7.2 BASIC NARROW GROUND SUBSYSTEM

7.2.1 Reliability Analysis

The reliability predictions were performed in accordance with the procedures in MIL-STD-756A and by using the prediction data in MIL-HDBK-217B as the primary source for failure rates.

The results of the reliability prediction for the mean-time-between-failures (MTBF) for the Basic Narrow ground subsystems are given in Table 7-1.

TABLE 7-1. BASIC NARROW GROUND SUBSYSTEM
R&M ANALYSIS

EQUIPMENT	MTBF (Hrs.)	MTTR (Mins.)
AZ Electronics	4580	
AZ Monitor	7760	
AZ Subsystem	2880	
AZ Maintenance Monitor (a)	19070	
EL Electronics	5570	
EL Monitor	8840	
EL Subsystem	3420	
EL Maintenance Monitor (a)	20870	
Ground Subsystem	1560	25.25
Maintenance Electronics	9965	

(a) Not included in subsystem MTBF/MTTR calculations.

In addition to the executive monitoring, maintenance monitoring is provided to aid in isolating failures to the faulty LRU. This maintenance monitoring is not included in the model since it has no effect on system operation and performs no executive or downgrading function. The MTBF of the maintenance monitoring was calculated, however, for inclusion in the calculations for average number of maintenance actions required and are given in Table 7-1. The reliability models are defined in Appendix C.

7.2.2 Maintainability Analysis

The maintainability predictions for the ground equipment were performed in accordance with MIL-HDBK-472, Procedure III. The results are a mean-time-to-repair (MTTR) of 25.25 minutes for the Basic Narrow configuration.

7.3 SMALL COMMUNITY GROUND SUBSYSTEM

The reliability and maintainability analyses for the Small Community equipments were performed under the same ground rules as for the Basic Narrow equipments. Results of the analyses are summarized in Table 7-2. The reliability models are defined in Appendix C.

TABLE 7-2. SMALL COMMUNITY GROUND SUBSYSTEM
R&M ANALYSIS

EQUIPMENT	MTBF (Hrs.)	MTTR (Mins.)
AZ Electronics	4350	
AZ Monitor	4250	
AZ Subsystem	2150	
AZ Maintenance Monitor (a)	11300	
EL Electronics	4470	
EL Monitor	5070	
EL Subsystem	2376	
EL Maintenance Monitor (a)	12620	
Ground Subsystem	1129	24.37
Maintenance Monitor	5962	.

(a) Not included in subsystem MTBF/MTTR calculations.

7.4 AIRBORNE EQUIPMENT

This section summarizes the results of the reliability and maintainability predictions for the Basic Narrow and the Small Community configurations of the airborne equipment.

7.4.1 Basic Configuration

The results of the reliability prediction are shown in Table 7-3. The prediction is based on an ambient temperature of 30°C, considered a typical environment for the equipment. The detailed reliability block diagram for the active Basic Narrow A/B configuration is given in Appendix E.

Maintenance monitoring equipment has been added to aid in fault location and isolation. Failures in this equipment do not cause degradation of system operation. A prediction, however, was performed for this equipment for use in determining system maintainability characteristics and is shown in Table 7-3.

TABLE 7-3. BASIC NARROW A/B SUBSYSTEM
R&M ANALYSIS

EQUIPMENT	MTBF (Hrs.)	MTTR (Mins.)
Angle Receiver/Processor	2696	
Control Panel	6135	
Executive Monitor	23300	
Aux Data Display	4141	
Maintenance Monitor (a)	79000	
A/B Subsystem w/o Aux Data	1733	22.57
A/B Subsystem w/Aux Data	1222	

(a) Not included in subsystem MTBF/MTTR calculations.

Estimates of maintenance times have been made for all elements of the Basic Narrow airborne equipment. The resultant MTTR values are shown in Table 7-3 where MTTR is defined as the time required to repair the airborne system after it has been removed from the aircraft.

7.4.2 Small Community Configuration

The predicted MTBF and MTTR for the Small Community configuration is shown in Table 7-4 for an ambient temperature of 30°C. The detailed reliability block diagram for this configuration is contained in Appendix E.

TABLE 7-4. SMALL COMMUNITY A/B SUBSYSTEM
R&M ANALYSIS

EQUIPMENT	MTBF (Hrs.)	MTTR (Mins.)
Angle Receiver/Processor	2255	30.0
Control Panel	5529	15.0
A/B Subsystem	1602	25.65

7.5 FIELD DATA

Experience with the Basic Narrow and Small Community equipments in the field support the previous theoretical analyses. Most of the logged failures occurred at NAFEC during the installation, checkout, and flight tests. Some were due to human error, e.g., shorting out the leads on IC's while checking or measuring system parameters. Two TWT's malfunctioned, but evidence indicates that these were caused by the prime AC power falling below specified limits. There have been no failures of the fine scan modulators or RF switches. The logged failures and their probable cause are listed:

<u>Failure</u>	<u>Probable Cause</u>
a) TWT (2)	prime power failure
*b) ± 15 VDC power supply (2)	filter capacitor
c) LED's in monitor drawer	unknown
d) I.C.'s	human error
*e) Manual switches for timing offset (intermittent failure)	mechanical vibration

*Used to estimate MTBF below.

<u>Failure</u>	<u>Probable Cause</u>
*f) Ground fault circuit breaker	unknown
g) TWT (1)	diesel generator failure
*h) I.C.	unknown

The four ground subsystems have been operated a total of approximately 46,000 hours. Using the calculated MTBF's from Tables 7-1 and 7-2, the predicted MTBF for the four ground subsystems is 655 hours. With the five true executive failures listed above, the actual MTBF to date of 8200 hours.

*Used to estimate MTBF.

SECTION 8.

CONCLUSIONS

8.1 GENERAL

The previous sections of this report have described the design and performance of two Prototype MLS configurations: a Basic Narrow and a Small Community configuration, each including the airborne and ground subsystems. The field tests at NAFEC demonstrate that the performance requirements for both configurations (Type 2 for Basic Narrow, and Type 1 for Small Community) were met or exceeded. In fact, both configurations proved capable of meeting the autoland requirements for Category III landings.

8.2 SIGNIFICANT ACHIEVEMENTS

Several state-of-the-art advances were achieved during the task. The principal areas of achievement are listed below, followed by a brief description of each.

- (a) Adapting the Rotman lens to step-scan in increments of 0.1 beamwidth (or less if desired).
- (b) construction of a fine-scan modulator in conjunction with (a).
- (c) development (through IR&D-funded efforts) of a technique for defining waveguide slot spacings, dimensions, and orientations to synthesize accurately a shaped pattern (the vertical waveguide elements).
- (d) modification of standard, commercial DME interrogators and transponders that increased the DME subsystem accuracy by more than 80 percent (600 feet to 100 feet).

In addition, significant achievements were made in the following areas:

- (e) implementation of a monitoring philosophy that enables fault location to the LRU level.
- (f) reductions in size and weight of the airborne equipments.
- (g) development of computer programs for accurately simulating each MLS configuration and its subsystems.
- (h) verification that MLS, ILS, and ALS could co-exist at a common site.
- (i) application of a quality control program through thorough testing from component to PC board to assembly to system test.

- (j) achievement of a high degree of commonality between the BN and SC configurations and between the subsystem in each configuration.

The Rotman lens was originally conceived as a mechanically scanned device where a horn feed would oscillate over the input (focal) arc. The first step was to replace the horn by a series of input probes. In order to obtain constant beamwidth scan increments, it was found expedient to space the inputs so that beams from adjacent inputs were cophasal and in space quadrature. This also involved adding a fixed electrical phase to each input.

In conjunction with the Rotman lens design, a variable, lossless, microwave power divider was produced. Although the technique used - varying the phase of inputs to a quadrature coupler - is not new, the power division accuracy that was obtained over the MLS frequency and temperature ranges in a limited production run (6 units) represents a singular accomplishment.

The design of a vertical slotted waveguide element was successfully accomplished through the application of a computer program which defined, via a Woodward synthesis, the amplitudes and phases of the slots. These amplitude and phase specifications were then transformed into mechanical specifications that defined slot orientation, dimensions, and spacing, taking into consideration the effect that mutual coupling would have on the complex excitation. This transformation was achieved through a series of design curves that were generated under a Bendix IR&D program.

An Aerocom DME transponder and a Bendix DME interrogator were modified so that the system two sigma range accuracy was increased from 600 feet to 100 feet.

A monitor design was formulated that provided fault determination and isolation down to the LRU level. Serious faults - those that resulted in a loss of system accuracy - would shut down the system in order to prevent the transmission of erroneous data. Less serious faults - those which caused an acceptable degradation - were determined and isolated to the LRU level so that preventive maintenance could be performed before the degradation increased and resulted in a system shutdown.

The size and weight of the airborne equipment was reduced below those specified through the application of IC's and microprocessors.

Approximately fifteen computer programs were developed during Phase III to aid in design and to provide a simulation capability. The simulation programs enabled array performance to be predicted without fabricating a model. For example, changes could be incorporated in the lens design using the design-aid programs. This permitted final array designs to be evolved with a minimal number of fabrication models. These programs also proved useful in verifying suspected sources of error, e.g., forward scattering from the field monitor horns and "dishpanning" of the apertures. This substantially reduced the time and costs that would have been associated with a "cut and try" method in the field.

8.3 PERFORMANCE AND DESIGN

Collocation tests were run on the Basic Narrow configuration with the Instrument Landing System (ILS) and Approach Lighting System (ALS) on runway 13/31. Interference tests were performed immediately after the Basic Narrow equipment was installed at NAFEC. No noticeable degradation of ILS performance was observed. Since it was impractical to remove the ILS and ALS equipments to test for the reciprocal interference, it was inferred from the measured flight data that the ILS and ALS did not contribute significant errors to the MLS.

A continuous program of testing - component, unit, subsystem, and system - contributed toward a system which experienced a minimal number of failures during the field tests. A reliability and maintainability analysis shows that system integrity met the operational requirements; field experience to date lends credence to this analysis.

Another objective of the Phase III design was to achieve a high degree of commonality in the MLS equipment. This has been done, as attested to by the following considerations. The BN AZ and the BN EL antennas used identical Rotman lenses. Scan angle and beamwidth are controlled by varying the number of inputs and the output element spacings, respectively. Further, this same lens can be used for a Back AZ antenna in the Basic Narrow Configuration.

The SC AZ and SC EL antennas also share a common lens design. Additionally, the SLS antennas for the BN AZ and SC AZ share a common design, as do the BN EL and SC EL SLS antennas. The forward ident antennas for both BN and SC are also identical, thus a total of seven array/lens designs are used for a total of sixteen antennas. This is summarized in Table 8-1, where the Roman numerals indicate the seven different designs.

TABLE 8-1. MLS LENS AND ANTENNA COMMONALITY

ANTENNA	BN	SC
AZ: Array Lens	I	I
Forward Ident	II	II
Left SLS	III	III
Right SLS	III	III
Rear SLS	=	III
Fly Left/Right	-	IV
EL: Array Lens	V	V
Forward Ident	VI	VI
Upper SLS	VII	VII

The RF scan switches for both BN and SC scanning arrays are identical, although the switches are arranged in different matrices to accommodate the different scan angle requirements.

The fine scan modulators, transmitters, and RF units are common to all four ground subsystems. Also, the beam steering units are common to a degree. That is, the BN AZ beam steering uses the same PC boards as the BN EL, but it requires additional boards to control the greater number of switches in the AZ switch matrix. The same PC boards are used in the EL system, as far as is permitted by performance constraints. This same PC board commonality is evident in the Local Control/Status, RF, and Monitor units of both configurations. A common design was also used for the field monitor horns, although the EL subsystems require a taller mounting post.

The BN equipment shelters are identical, as is most of the environmental control equipments in both BN and SC systems.

The same concept of PC board commonality has been incorporated into the airborne equipments where permitted by physical and electrical requirements.

Extensive field testing of the two configurations has shown that all Phase III specifications (CAT I for SC and CAT II for BN) and design goals (CAT III Autoland for both configurations) were met or exceeded. These tests included flight and static tests at NAFEC as well as live demonstrations at the following airports:

<u>Airport</u>	<u>System</u>
Cape May, New Jersey	SC
Buenos Aires, Argentina	BN
Tegucigalpa, Honduras	SC
Kristiansand, Norway	BN, SC
Chaleroi, Belgium	SC
Dakar, Senegal	SC
Nairobi, Kenya	SC
Shirez, Iran	SC

8.4 IDENTIFIED PROGRAM AREAS

The Phase III MLS equipments have met all requirements and design goals. Despite this successful performance, there are areas where improvements can and should be included. Some of these became evident during field testing. For example, water ingestion by the radome caused discernable errors and will require changes to vendor and installation specifications. It was also observed that water running over the radomes during a heavy rain reduced the radiated power to a level that triggered an executive fault and shut the system down. Solutions to both of these problems are underway.

In other instances, improvements were identified during the design and fabrication phases of the program, but were not implemented due to cost, schedule, and/or contractual constraints. All of the major improvements noted to date are identified in the next section.

SECTION 9.

DESIGN IMPROVEMENT PROGRAM

9.1 INTRODUCTION

The Basic Narrow (BN) and Small Community (SC) systems have been described as they were built, tested, and delivered to the FAA at NAFEC. As is usual with developmental and prototype hardware, areas where modifications and improvements could be incorporated into the system became evident during the design and testing. However, it was not often possible to incorporate these changes into the delivered system and remain within the established program cost and schedules. In this section are listed the major improvements which could be incorporated into the design if additional Phase III equipments were built. In some cases, additional study and development are required. Due to the high degree of commonality between the BN and SC ground subsystems, the recommended improvements are discussed in two main subsections, one for the ground subsystems and one for the airborne equipments.

9.2 GROUND SUBSYSTEMS IMPROVEMENTS

9.2.1 General

To facilitate the description of the recommended improvements, the discussion will be organized into the major equipment groups as defined in the subsystem block diagrams, Figures 2-5 and 2-21.

9.2.2 Antennas and Radomes

The basic antenna characteristics, such as coverage, gain, side lobes, etc., are satisfactory as designed. However, as mentioned in Section 8, there are three areas where improvements could be incorporated.

Firstly, a film of water over the radome, such as might occur during a very heavy rain, may cause the ERP to degrade to a point where an executive fault may be triggered. A solution to this problem is being evaluated and will probably involve a retrofit to the equipments in the field. (See "The Effect of Rain on the MLS Phase III Radome" in Appendix F.) However, this fix may not be the optimum solution to incorporate into new equipment.

The method under investigation currently is to cover the radome with a material, such as Tedlar, which will shed the water more quickly than the fiberglass radome. Other approaches which should be evaluated are, for example, tilting of the radome to inhibit water from running over the entire face, and incorporating a small overhang into the apertures to decrease the amount of rain incident on the face.

Secondly, warpage of both the AZ and EL apertures was noted during tests at NAFEC. The deformations were due to release of internal stresses apparently during handling and transportation. To prevent this occurrence on subsequent equipment, we would anticipate use of a stress-relief process on the antenna cases prior to the installation of equipment, and consider a different mounting arrangement with the aperture structure isolated from the case structure. Also, to avoid the imposition of excessive stresses during shipment, tie-down procedures would be formulated.

Thirdly, it was found that water had migrated to the inside cavities of the double-walled Azimuth radome, the leaks occurring generally around the attaching screw holes. The problem has been solved by strengthening the radome around each bolt hole, thereby precluding any mechanical damage which can sometimes occur because of the tightening loads. Also, a change in materials will be considered, such as substituting a closed-cell foam, which would provide no spaces into which the moisture could migrate.

9.2.3 Field Monitor Horn

During testing at NAFEC, it was discovered that scattering of energy by the field monitor horns and supports was causing discernible errors around runway centerline. Work was immediately started to design and fabricate a monitor antenna with a smaller cross section. Although preliminary tests at NAFEC indicated that the new design is satisfactory, final flight test data has not been reduced. If this data shows that the scattering problem has been reduced to an acceptable level, the new monitor antenna design should be incorporated into the system design. In addition to the use of a reduced cross section monitor, the location of the monitor horn away from runway centerline should be considered. The error caused by the scattering would then occur in a region where the error specification is larger and the scattering error would not be as critical.

9.2.4 TWT Amplifier

The TWT amplifier has one of the highest component failure rates in the ground subsystems. It is recommended that the use of solid-state transmitters be thoroughly investigated. Although the power output of known C-band solid-state transmitters does not approach the 20 watt output of the TWT, the small size of the solid-state transmitter would enable it to be mounted in the antenna enclosure near the antenna input, thereby eliminating the 3 to 4 dB cable loss in the BN system. This would also require that the SLS and Forward Ident antennas of the BN AZ subsystem be mounted on the AZ antenna enclosure. This is already done in the BN EL antenna and the SC system.

9.2.5 RF Unit

The exciter units have exhibited some frequency instabilities which make them suspect for long-term, maintenance-free operation. In particular, some crystals appear to be aging more rapidly than expected. The selection of crystals should be reviewed.

9.2.6 Monitor Electronics

In the BN AZ subsystem, the scan switch monitor does not operate properly when the maximum scan angle is reduced to the point where the end switches do not have RF power applied to them. This condition should be corrected so that the scan switch monitor will operate under all specified conditions.

Some LO drift has been observed in the monitor receiver using the RF input from the field monitor horn. This requires that the receiver be retuned more frequently than is desirable. The design of this unit and the component selection should be thoroughly reviewed.

9.3 AIRBORNE EQUIPMENT IMPROVEMENTS

9.3.1 General

Prior to discussing design improvements, a review of the existing status of airborne equipments is in order. During Phase III, all airborne MLS equipments, except for DME equipments, were designed as prototype or preproduction hardware in anticipation of the next MLS phase being a production phase. These prototype equipments are essentially ready for production and, as a result of field testing and feedback, can be improved with minor design changes which are typically expected during the initial stages of a product life cycle. The DME equipment, on the other hand, was designed during Phase III as a feasibility test model to demonstrate higher ranging precision than that available for conventional L-band DME. Consequently, the DME equipment should be subjected to a new design iteration which will yield a more cost-effective ARINC prototype/pre-production design.

The major equipments considered for design improvements are the angle receiver and the DME interrogator. The system peripherals, including the control panel, the auxiliary data display, and the DME indicator, receive less emphasis in the design improvement program since they are most likely to be changed for specific customers to suit their own particular

needs. The use of existing aircraft controls and displays, where feasible, will be pursued by some users, while other users may integrate controls and displays or expand/decrease the existing control/display requirements.

9.3.2 Angle Receiver

Following the delivery of the equipment and throughout the field test and evaluation program, modifications/design improvements have been made, as appropriate, to improve performance and reliability. The significant modifications already completed are discussed below as a matter of record. In addition, there are several significant modifications still in process (paragraph 9.3.2.2), and finally, a design improvement in the frequency synthesizer is recommended for incorporation in any future receivers.

9.3.2.1 Modifications/Improvements Completed During Test And Evaluation Period

- a. Temperature/Vibration Improvements - After approximately one year of field operation on the Phase III airborne receivers, there were indications that equipment operation would be more reliable with some minor thermal and vibration modifications. A series of temperature/vibration modifications were made and subsequent operation indicates that they were successful. These modifications are summarized as follows:
 - (1) Vibration Resistance Sockets - Some of the IC's were found to vibrate partially out of the PC board sockets after long periods of flight tests. The original sockets were replaced with "vibration resistant" sockets and no further problems have been identified.
 - (2) PC Card Retainer Pins - With the use of "low insertion" connectors on the PC cards, a PC card retainer pin is needed at the top of the card cage to prevent the cards from being "unseated" in an airborne environment.
 - (3) Equipment Reliability at Elevated Temperatures - There were two high temperature modifications to enhance receiver operation. The first consisted of replacing original PROM's (specified to 70 degrees C) with PROM's vendor selected to operate to 100 degrees C. The second temperature modification consisted of the addition of a small 400 Hz blower within the receiver package. The

movement of a small amount of air lowered the temperature in the receiver card bay by about 25 degrees C. These temperature modifications have improved the receiver reliability at elevated temperatures.

- b. Angle Receiver CMN Reduction - This modification was motivated by a theoretical analysis which indicated that the Phase III receiver Control Motion Noise measurements were almost 2.5 times larger than the theoretical predictions. An initial investigation revealed that: (1) power supply noise was being coupled into the A1 signal processing board because of inadequate ground plane, and (2) the quantization noise resulting from the 8-bit A/D amplitude conversion of the beam envelope was not filtered. Design modifications consisted of adding a 26 kHz 2-pole filter which removed the A/D beam envelope quantization noise, and a new layout of the A1 board which eliminated the power supply noise. This modification reduced the receiver noise by approximately a factor of 2.3 to a level of 0.0045 degree (2σ) as theoretically predicated.
- c. Extended AZ Processing From ± 40 Degrees to ± 60 Degrees - The original Phase III BN receiver designs were configured to process and display (Aux Data Display) azimuth angles to ± 40 degrees as required by the BN specifications. The desire to use these receivers with the wider coverage systems (Basic Wide) required a change in the processing (software) and a hardware change to the Aux Data Display. These changes have been successfully implemented.
- d. Drive Signal for Control Panel Clock - When loaded with a highly capacitive load, this clock line was susceptible to noise and caused the receiver "fail" light to intermittently flash and generate system flags. An additional TTL driver was added to the A3 card and has corrected this problem.
- e. Reduction in CDI Jitter - In the original processor, the "least significant bit" (LSB) for EL was 0.04 degree and for AZ 0.04 to 0.08 degree, depending on the scale factor. This caused a quantization jitter on the CDI. The software was modified to always select the smallest LSB possible for the selected glide slope and the azimuth scale factor. This change has typically resulted in an order of magnitude improvement and an acceptable CDI display.

9.3.2.2 Design Improvements Presently Being Implemented - There are two notable design modifications presently being implemented: 1) the incorporation of the Back Course Azimuth processing function, and 2) the improvement of the receiver AGC operation.

The BC AZ function was not included in the BN design. This processing function is a major software change and is presently being implemented in the Phase III processor software.

Recently, in test with higher gain Basic Wide type ground antennas, some of the Phase III receivers have shown signs of saturating at very close ranges. This is due to several things: 1) higher gain of 1-degree antennas, 2) higher gain in some of the receivers, and 3) the AGC that functions on the average value of the received signal was not strongly activated. The Phase III Receiver AGC technique is being reviewed and a design modification is currently being implemented.

9.3.2.3 Recommended Future Design Improvements - Testing of prototype angle receivers has indicated that the spurious response performance on a few channels is slightly below specification limits and that the receiver noise figure on these channels is marginal with respect to the specification. A detailed evaluation of synthesizer performance should be performed to determine if corrective action is feasible with minor redesign or if major redesign is required.